GPU TECHNOLOGY CONFERENCE

S9617

英業達集團 Inventec

Edge AI in Smart Manufacturing: Defect Detection and Beyond

Trista Chen, Chief Scientist of Machine Learning of Inventec

Wei-Chao Chen, Co-founder of Skywatch & Head of Inventec AI Center

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創新 Innovation　品質 Quality　虛心 Open Mind　力行 Execution

Inventec

Speaker Bio

Trista Chen

- Chief Scientist in Machine Learning, Inventec Inc.
- Serial Entrepreneur at the Bay Area
- Staff Research Scientist, Intel Corp.
- Video Architect, NVIDIA Corp.

- Ph.D., CMU ECE

Wei-Chao Chen

- Head of AI Center & Chief AI Advisor, Inventec Inc.
- Co-Founder & CEO, Skywatch Inc.
- Senior Research Scientist, Nokia Palo Alto
- Graphics Architect, NVIDIA Corp.

- Ph.D., UNC Chapel-Hill CS

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Smart Manufacturing

https://medium.com/@kenmacken/who-turned-off-all-the-lights-470dc797fd0f

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Lights-Out Factory

https://medium.com/@kenmacken/who-turned-off-all-the-lights-470dc797fd0f

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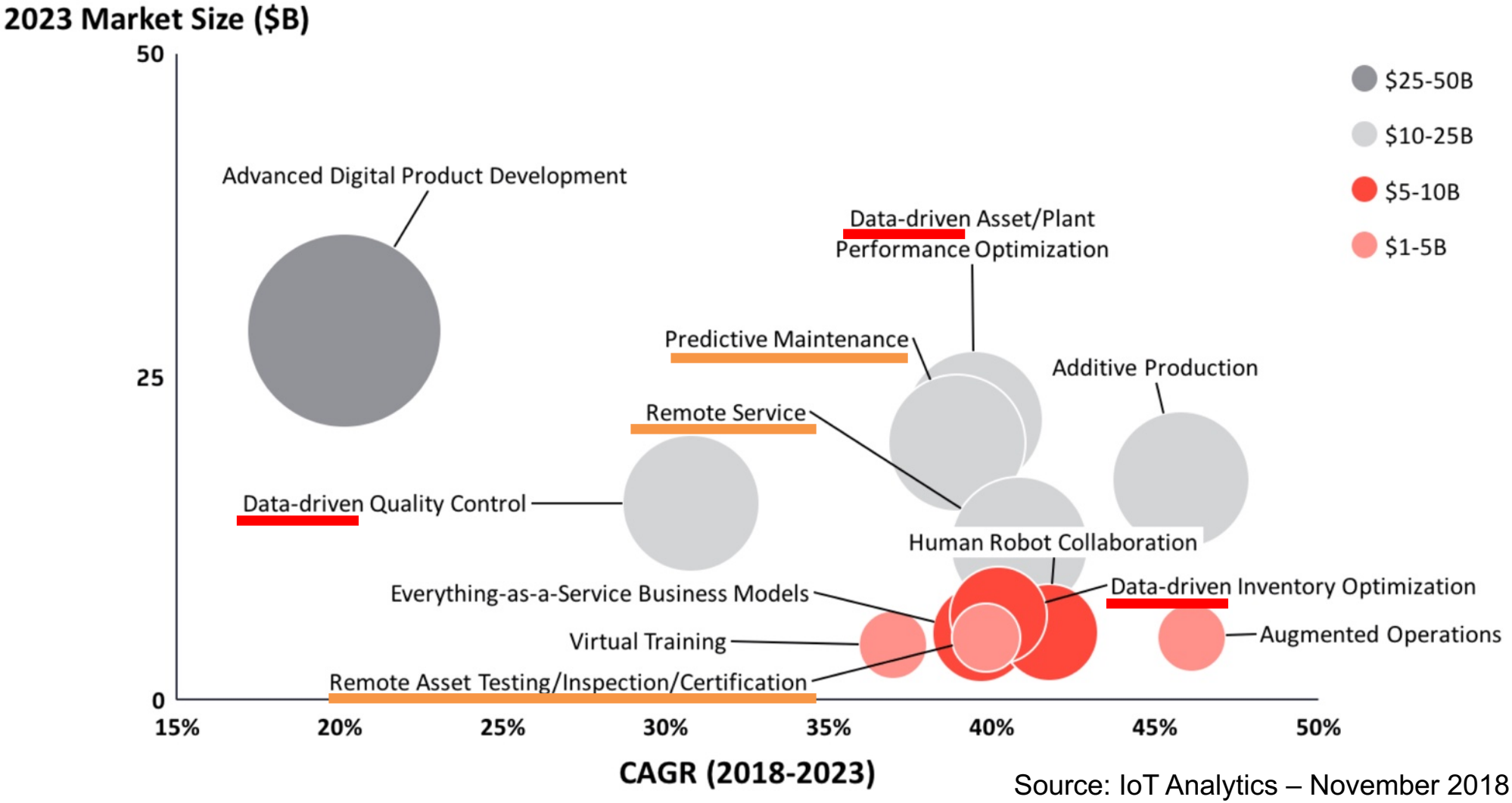
Top 12 Industry 4.0 (I4.0) use cases



Source: IoT Analytics – November 2018

Manufacturing stores more data than any other sector – an estimated two exabytes ($2 \cdot 10^{18}$ bytes) in 2010.

Source: McKinsey & Company, *"Is manufacturing 'cool' again?"* 2013

About Inventec

- Public company (Since 1975; Taipei, Taiwan)
- Tier 1 electronics manufacturer
- Annual revenue USD $16B+ (2018)
- Factories in Taiwan, Shanghai and Chongqing

Personal Computers
Laptops

Enterprise Computers
Servers

Solar Energy

Smart Devices
Medical Devices

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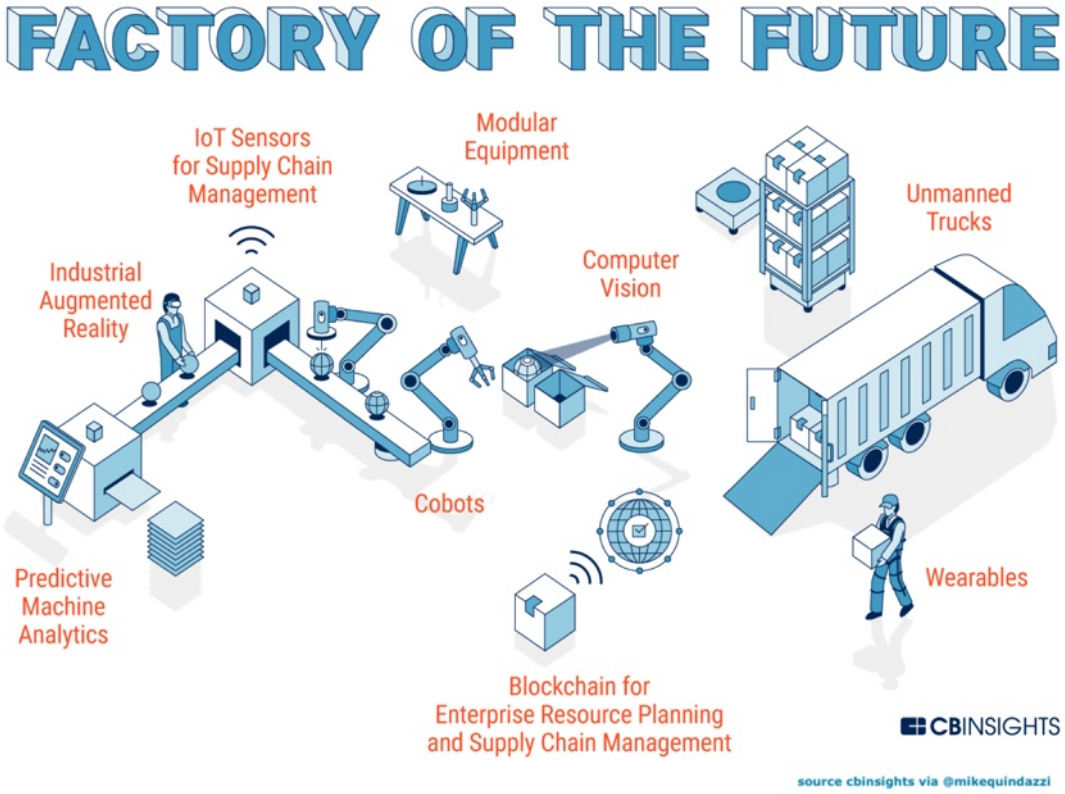
AI for Smart Manufacturing



- Process Automation
  - Automatic optical inspection
  - Production scheduling
  - Automatic testing
- Predictive Analysis
  - Order forecast
  - Production / yield prediction
  - Predictive maintenance

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Inventec AI Center

Smart Manufacturing

Automatic optical inspection
Order forecast
Production scheduling
Test automation
…

Future Product

AIOT / Smart City applications
Medical devices
Robotics
Computation Platform
….

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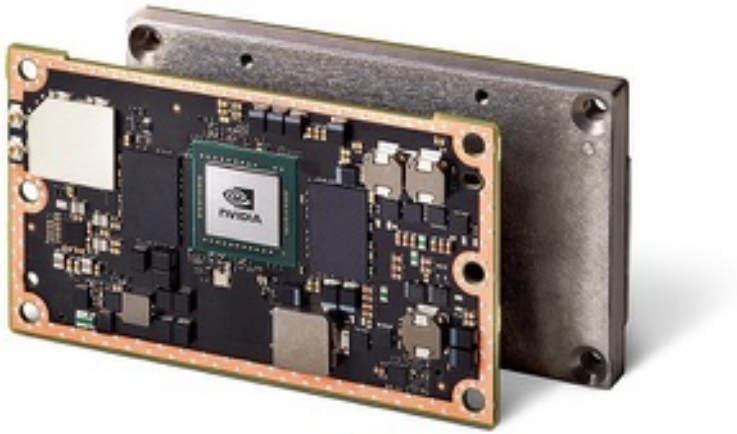
Why Edge AI?

- Privacy
- Reliability
- Network Efficiency



JETSON TX2 MODULE

•NVIDIA Pascal™ Architecture GPU
•2 Denver 64-bit CPUs + Quad-Core A57 Complex
•8GB L128 bit DDR4 Memory
•32GB eMMC 5.1 Flash Storage
•Connectivity to 802.11ac Wi-Fi and Bluetooth-Enabled Devices
•10/100/1000BASE-T Ethernet

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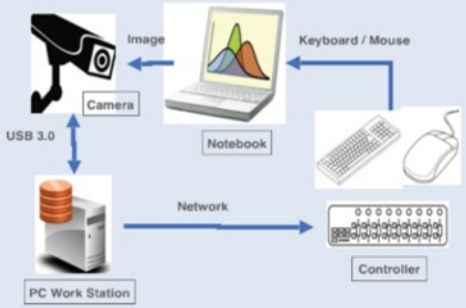
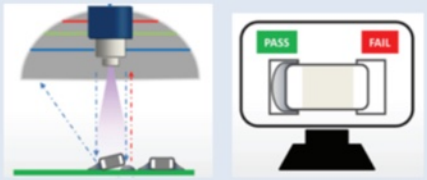


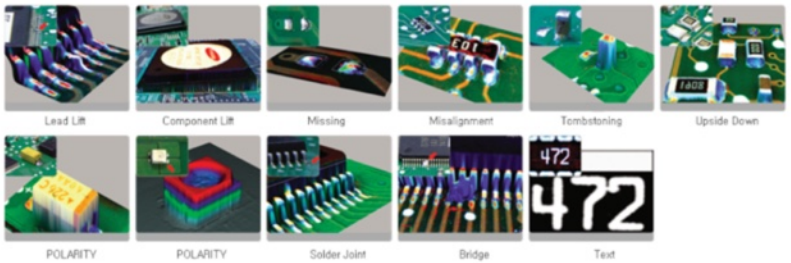
Laptop Testing Robot

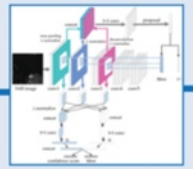
AOI **Re-inspection** for SMT lines and PCBs

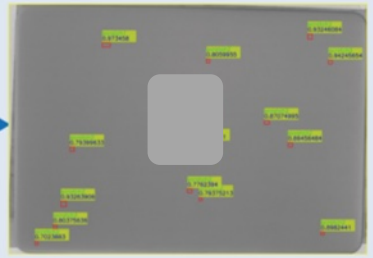


AOI Machine

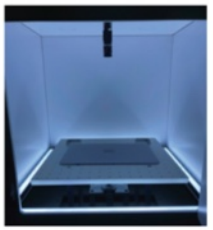
AOI Re-inspection

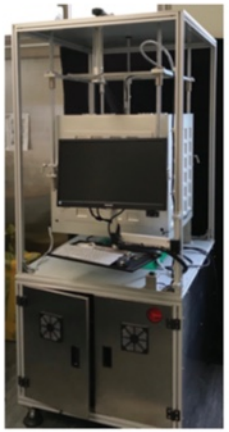






Laptop Surface AOI





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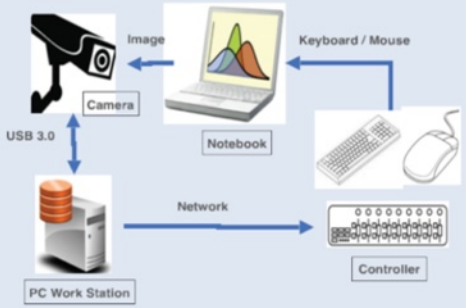
Laptop Testing Robot



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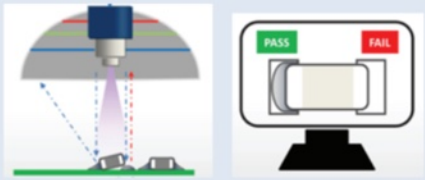
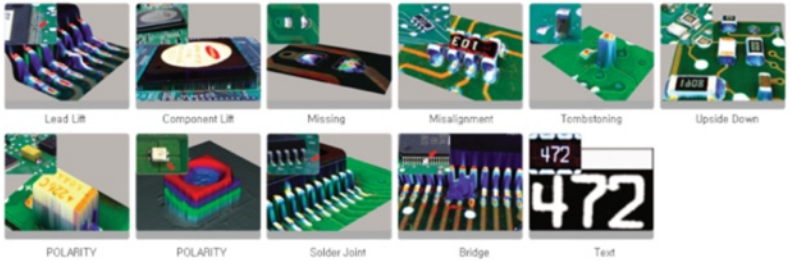
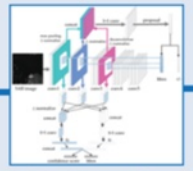


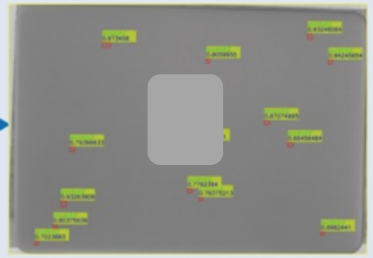
AOI Machine

AOI Re-inspection

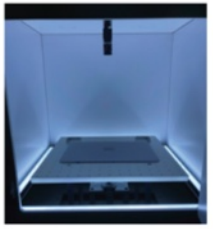




DL detection



Laptop Surface AOI



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1. Laptop Testing Robot

Background

- Millions of laptops manufactured every month
  - Similar basic design, many different configurations
  - Production tests are *mostly* automatic

1. Laptop Testing Robot

Background

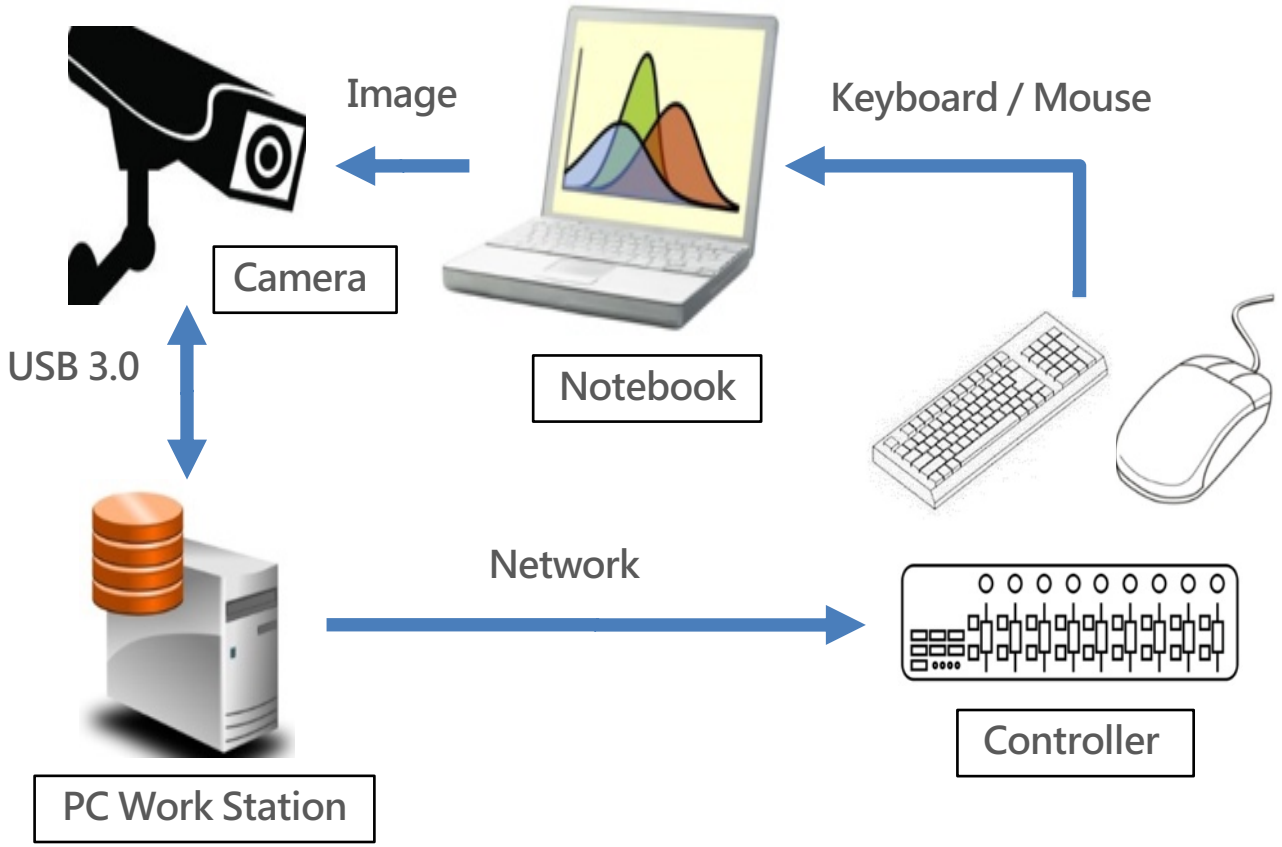
- Product approval is labor intensive
  - Takes weeks to certify for mass production
  - ~1M test assets
  - Hundreds of people running the tests

1. Laptop Testing Robot

Motivation (least -> most important)

- Labor cost and management
- Time-to-market
  - Regression tests take weeks / months to complete
- Increase confidence
  - The management confidence level about manual testing is only around 70%.

1. Laptop Testing Robot



By: Jimmy Ou, Wei-Chao Chen, et al. of Skywatch
Collaboration with Joseph Shi, Jack Hung & Inventec QA Engineers

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1. Laptop Testing Robot

Mechanical / electrical keyboard and mouse

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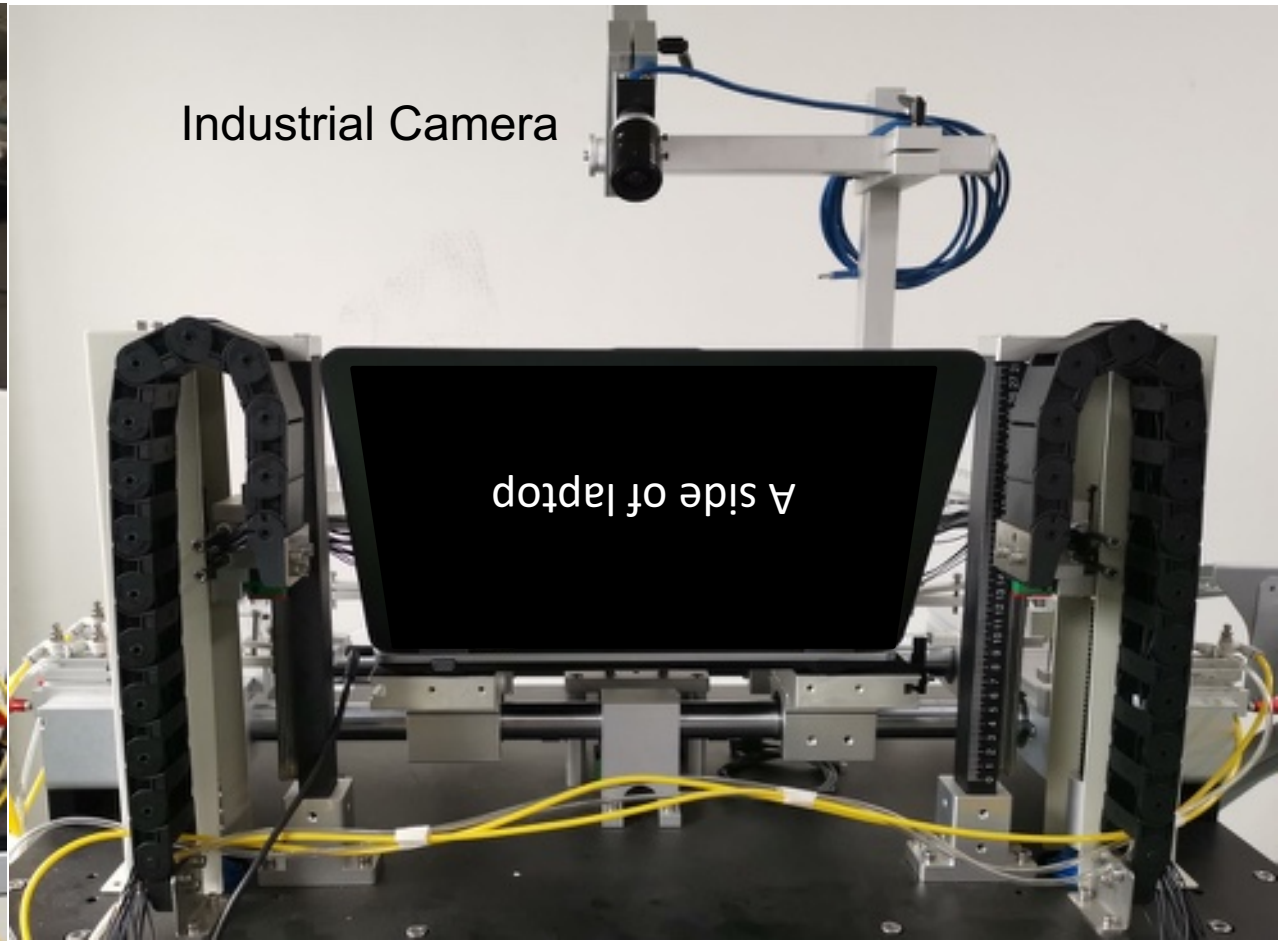
1. Laptop Testing Robot

Camera with computer vision capability



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1. Laptop Testing Robot

- Computer Vision (OpenCV)
  - Perspective correction
  - Edge detection & denoising
  - Template matching

- Tesseract OCR
  - LSTM-based NN OCR engine

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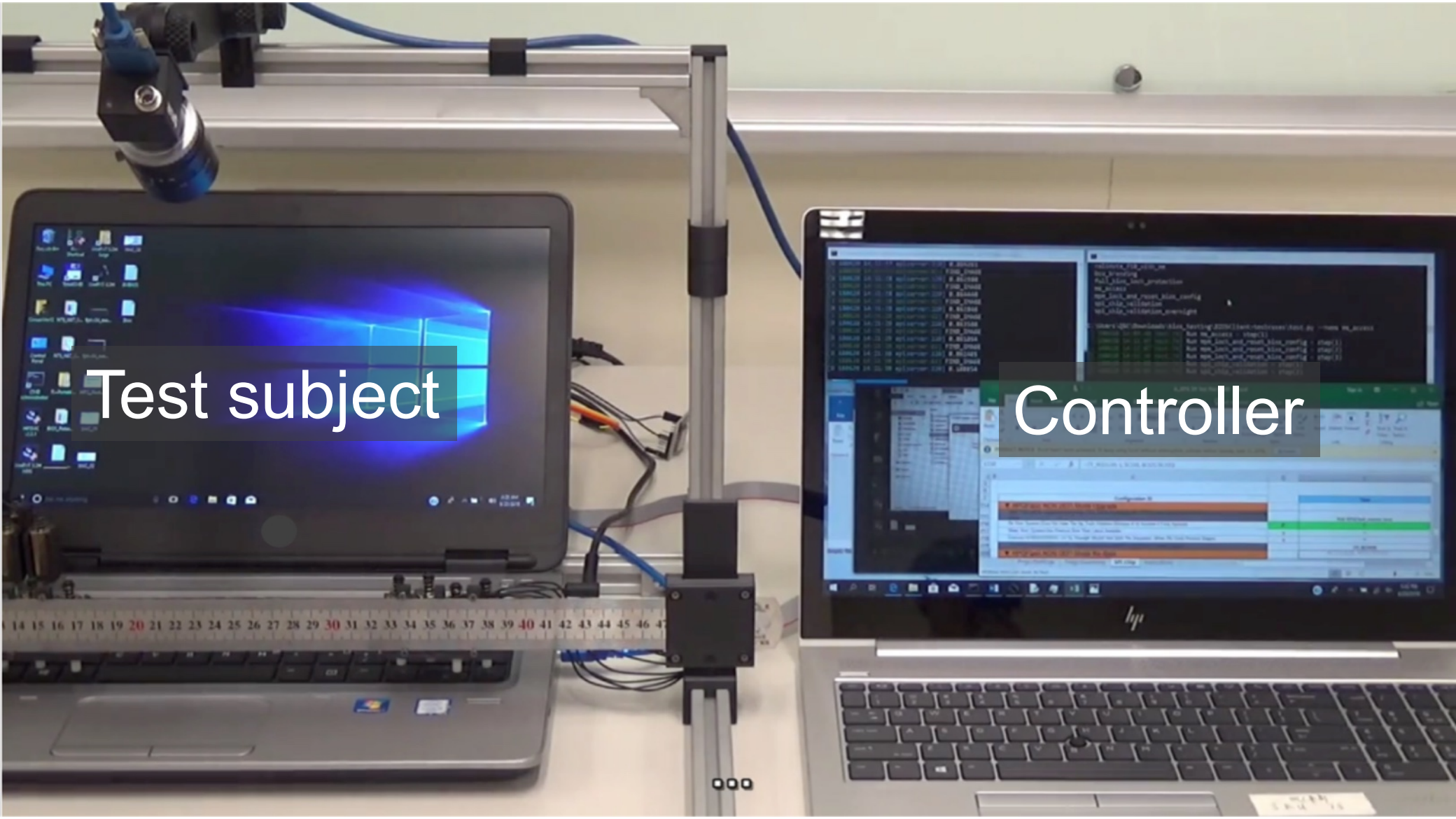

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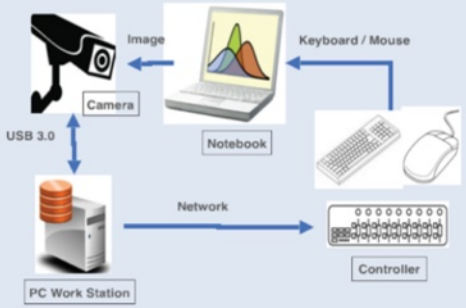
1. Laptop Testing Robot

Future Opportunities

- Automatic testing script generation
  - from human-readable to machine-readable test cases
  - Close-loop verification is hard
- Scheduling optimization
  - Reshuffle test levels and orders to speed up process
- Monkey testing?



Laptop Testing Robot

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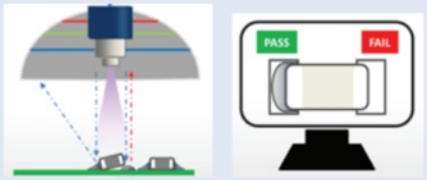
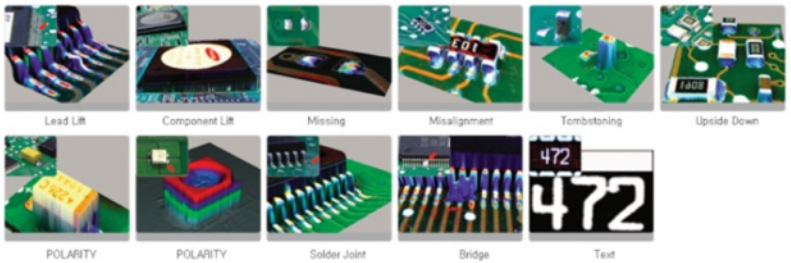
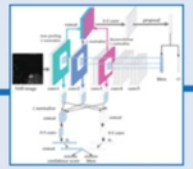


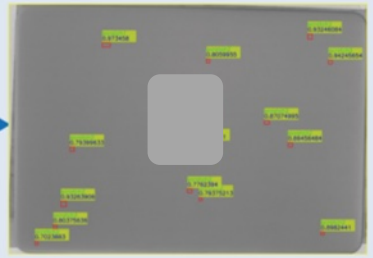
AOI Machine

AOI Re-inspection

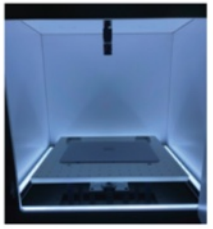




DL detection



Laptop Surface AOI



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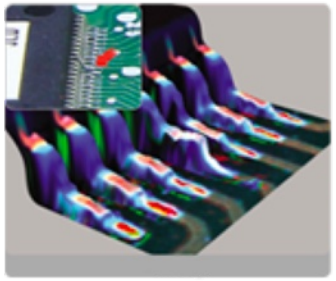
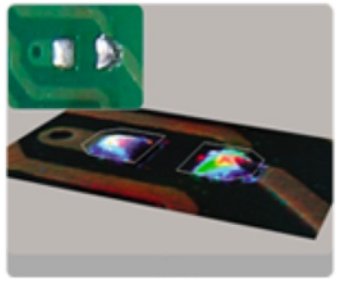
2: AOI Re-inspection

Common SMT defects


Lead Lift


Component Lift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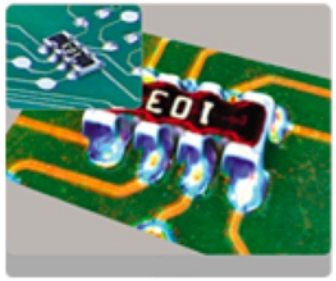
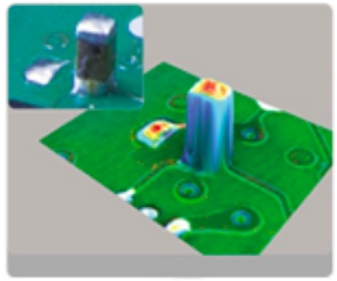
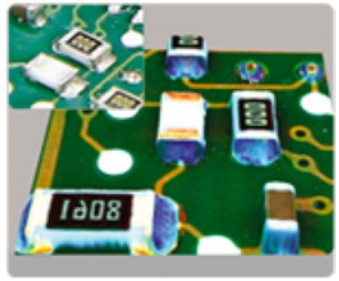
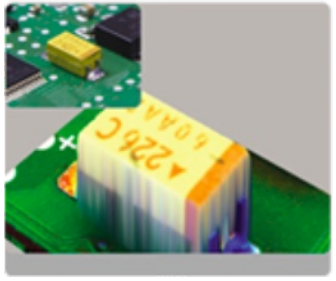
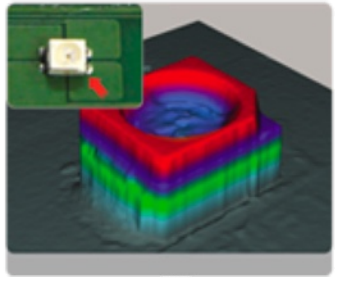

Misalignment


Tombstoning


Upside Down


POLARITY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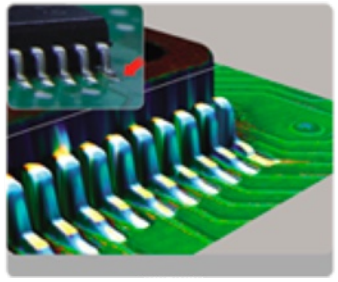
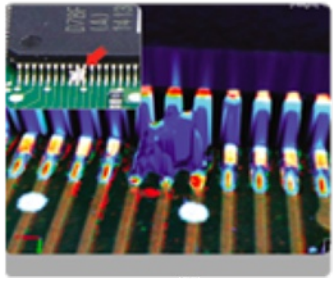

Solder Joint


Bridge

Text

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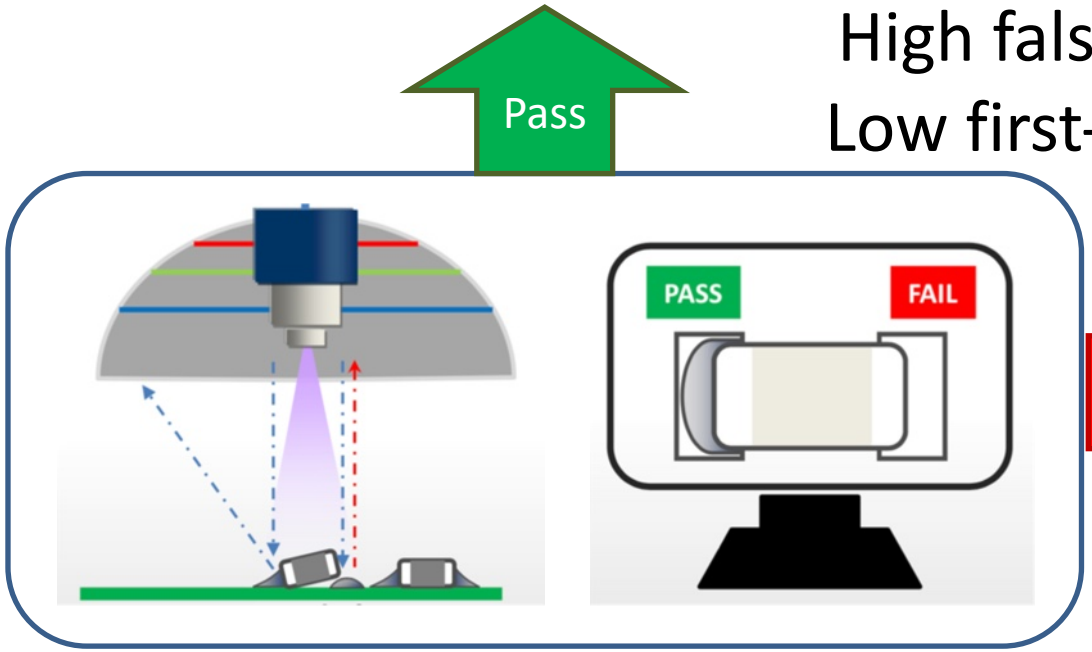
2: AOI Re-inspection



High false positive
Low first-pass yield

Fail

AOI Machine

Re-inspection
by human

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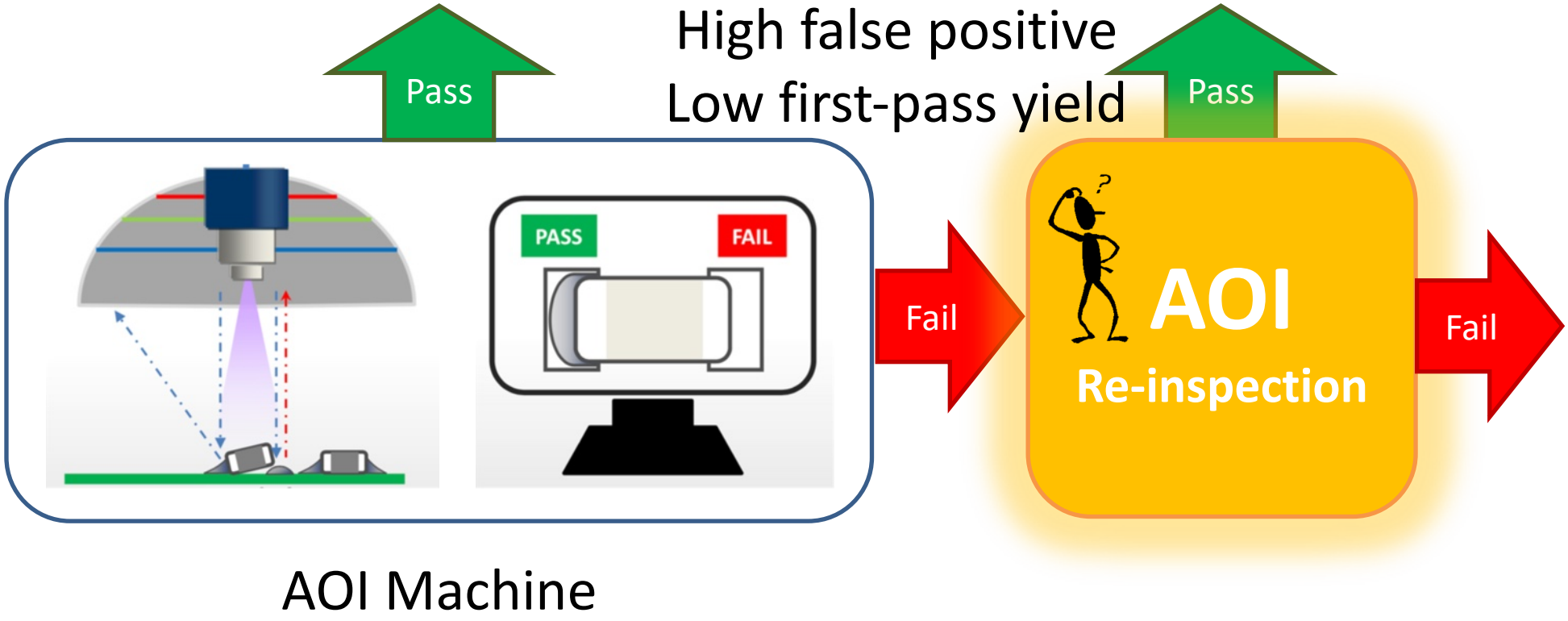
2: AOI Re-inspection



By: 許正翰, 呂明峻, 張文于 of NTU & advised by Wei-Chao Chen of Skywatch & NTU & Trista Chen of Inventec
Data & domain knowledge provided by Jessie Huang, Peter Chu @ TAO, among others

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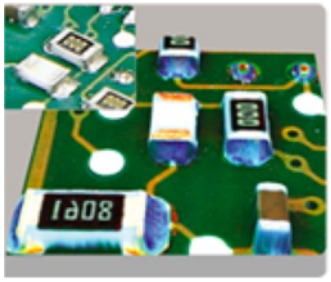
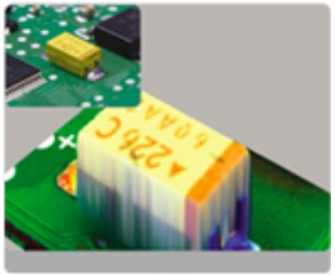
2: AOI Re-inspection



Upside Down



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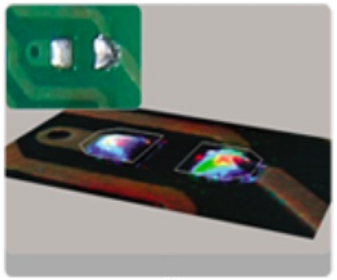

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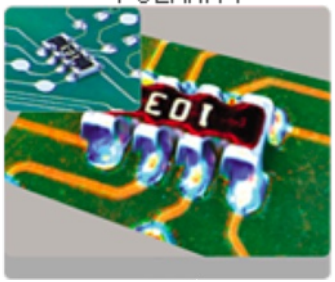
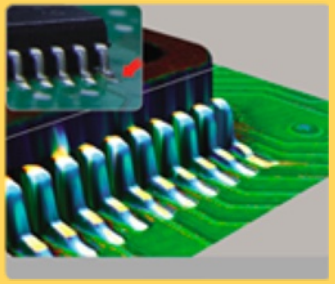


Misalignment



Solder Joint

Lead Lift

Traditional
Computer Vision
defects w/ well-defined rules

Deep Learning
defects w/ intuitive descriptions

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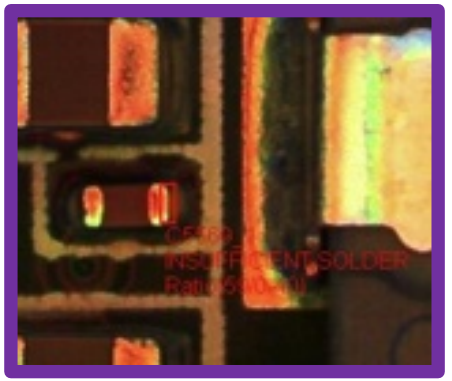
2: AOI Re-inspection

0. Excess Solder (true)

2. Insuff. Solder (true)



1. Excess Solder
(false positive → pass)

2. Insuff. Solder
(false positive→pass)

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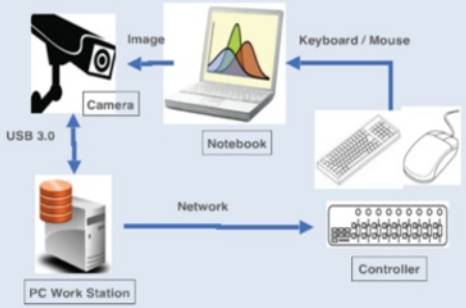

Laptop Testing Robot

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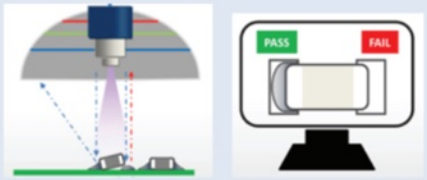
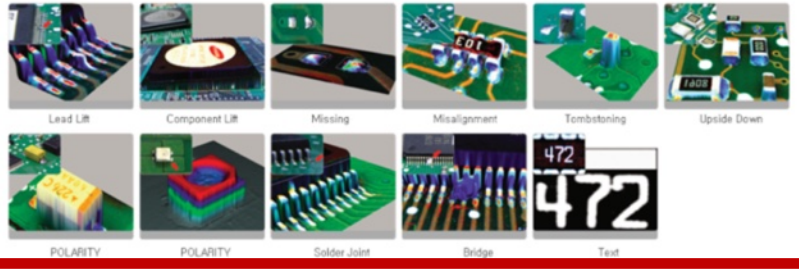
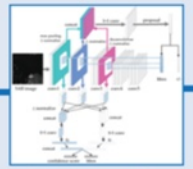
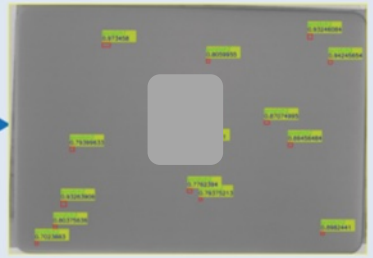


AOI Machine

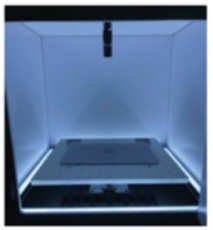
AOI Re-inspection





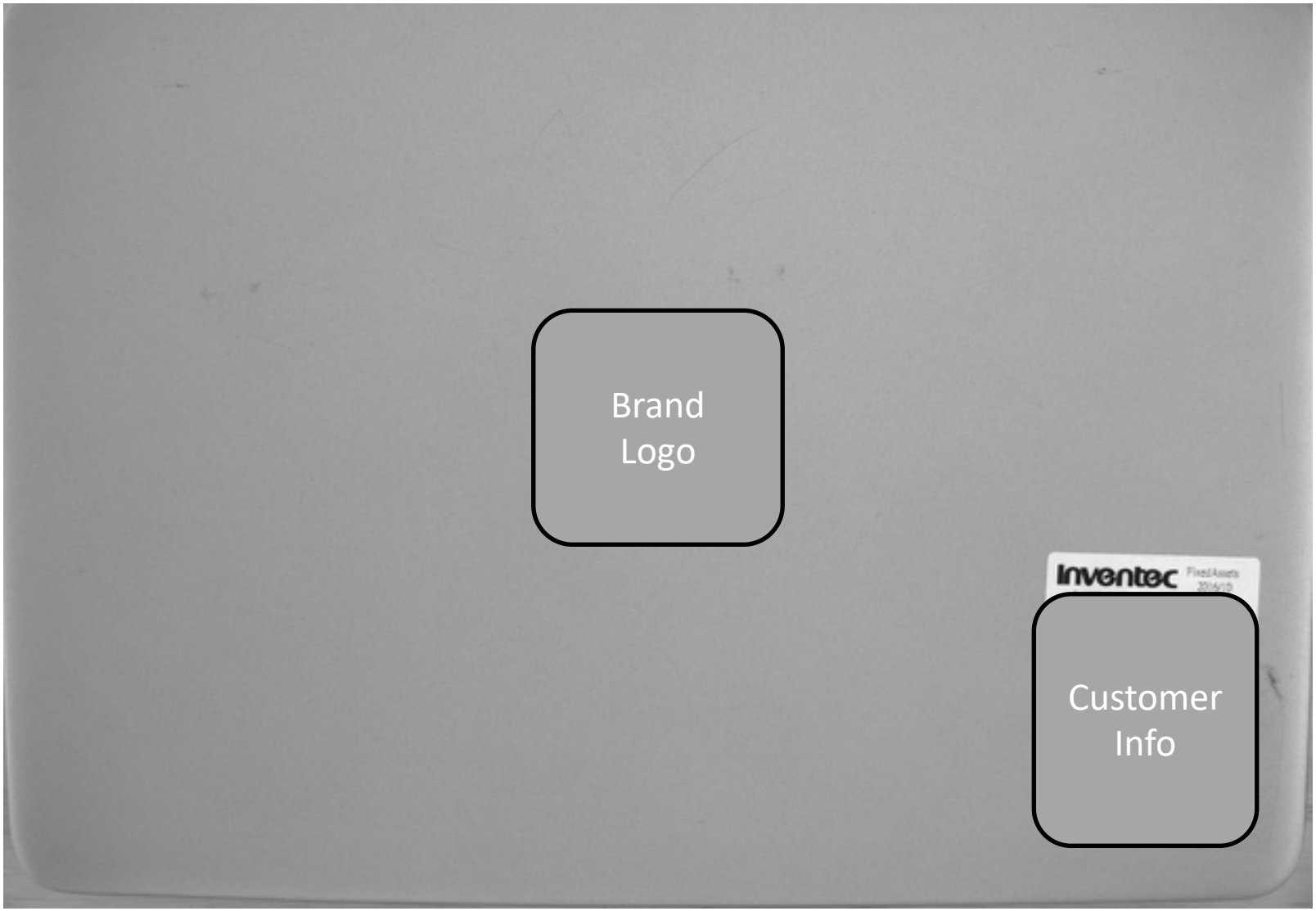


Laptop Surface AOI



Inventec

3. Laptop Surface AOI



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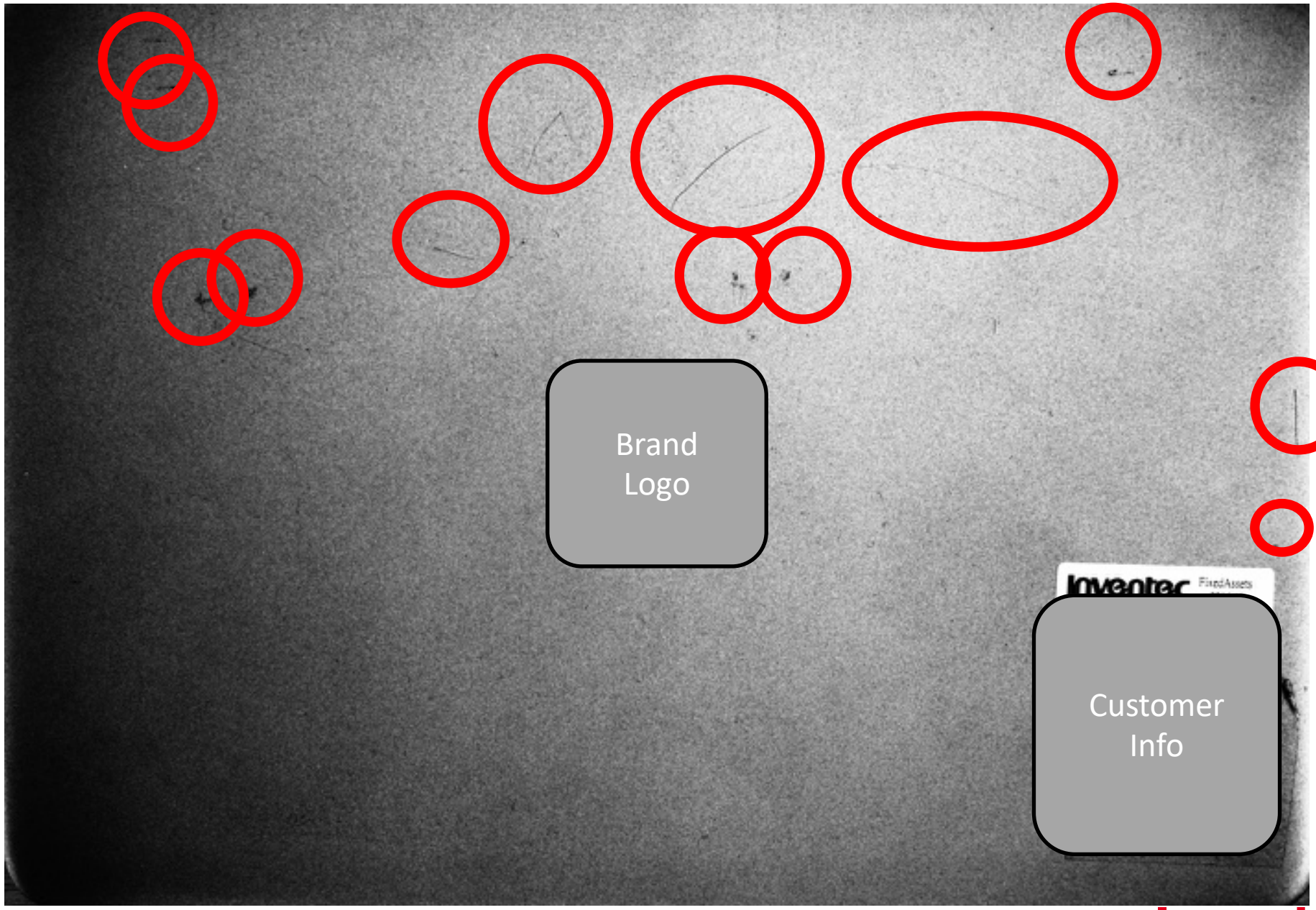
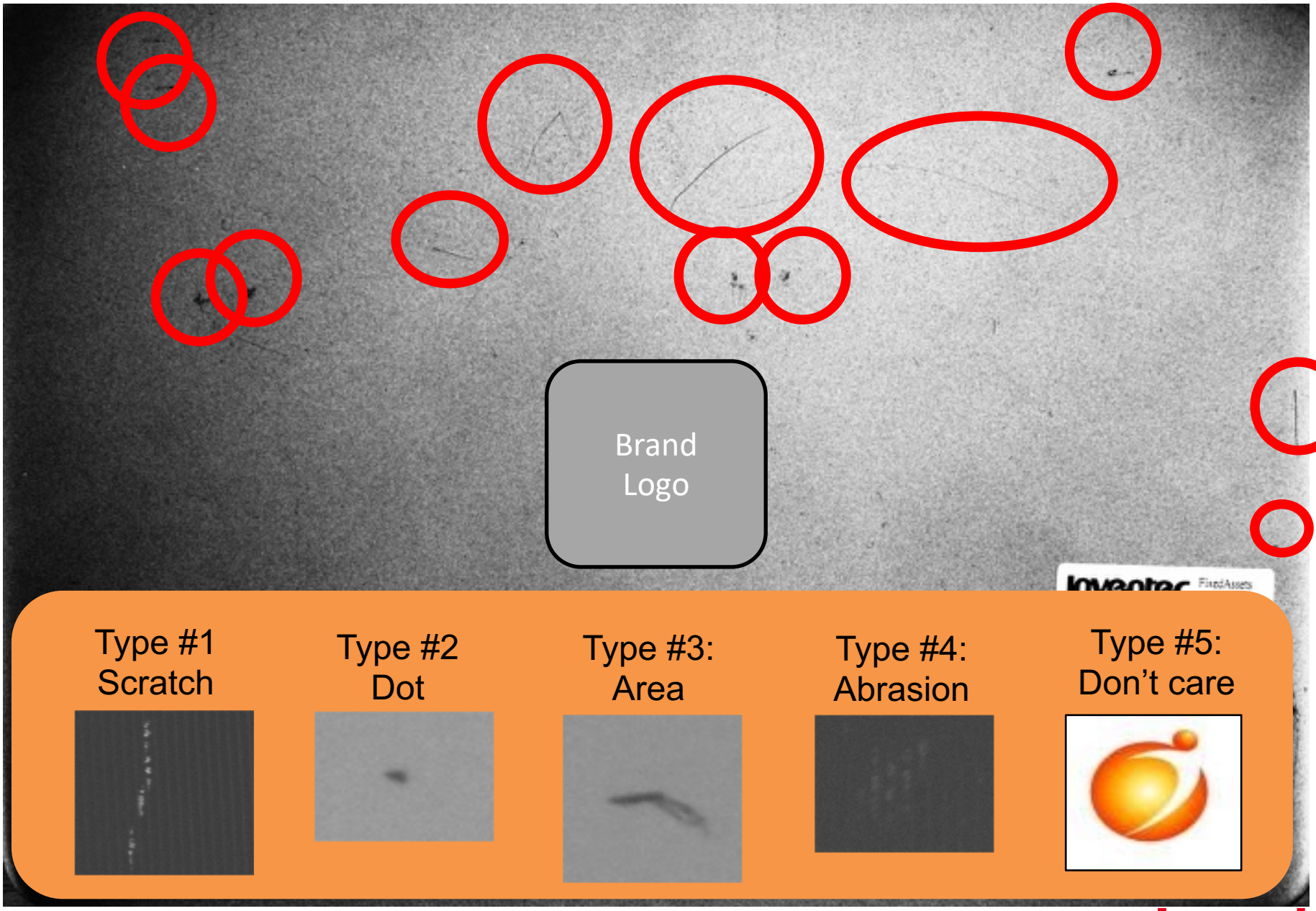


Inventec


Brand
Logo
Type #1
Scratch
Type #2
Dot
Type #3:
Area
Type #4:
Abrasion
Type #5:
Don't care

Inventec

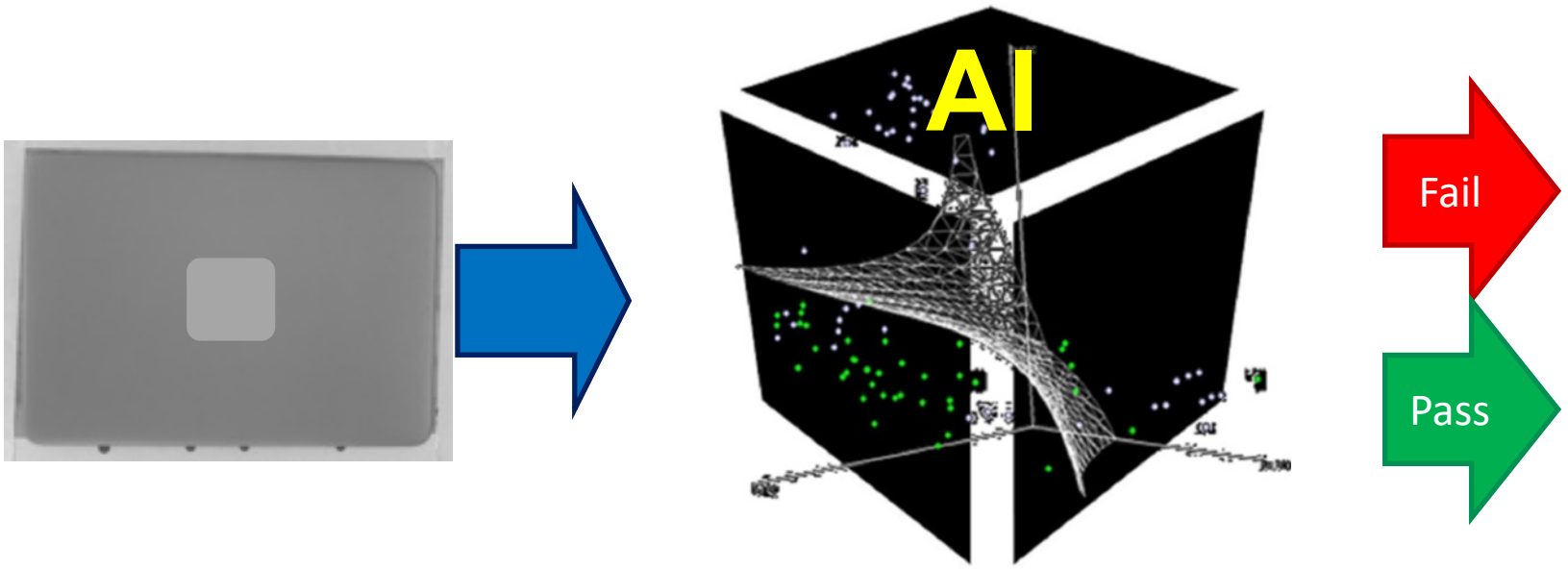
3. Laptop Surface AOI

Defect type	Class A spec	Class B spec
Scratch	Length: 12mm Acceptable: 2 lines	Length: 20mm, Acceptable: 2 lines
Dent	0.5 mm2 < size < 0.7mm2 Acceptable: 2 points	0.5 mm2 < size < 1mm2 Acceptable: 3 points
...		

Human readable rules

Inventec

3. Laptop Surface AOI



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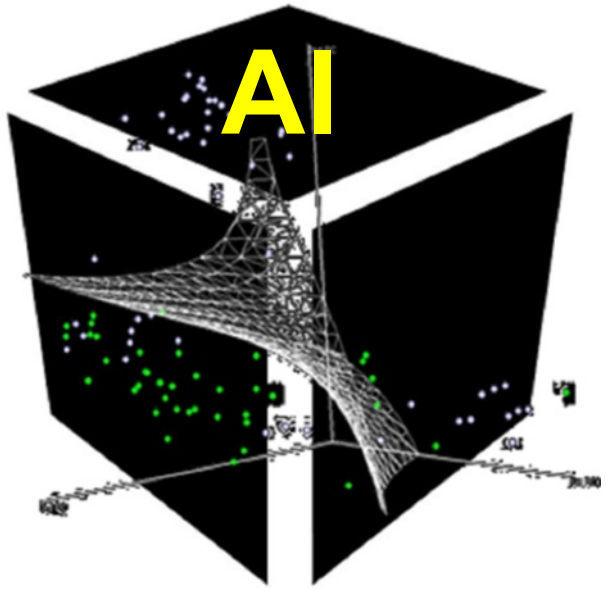
...		

Human readable rules

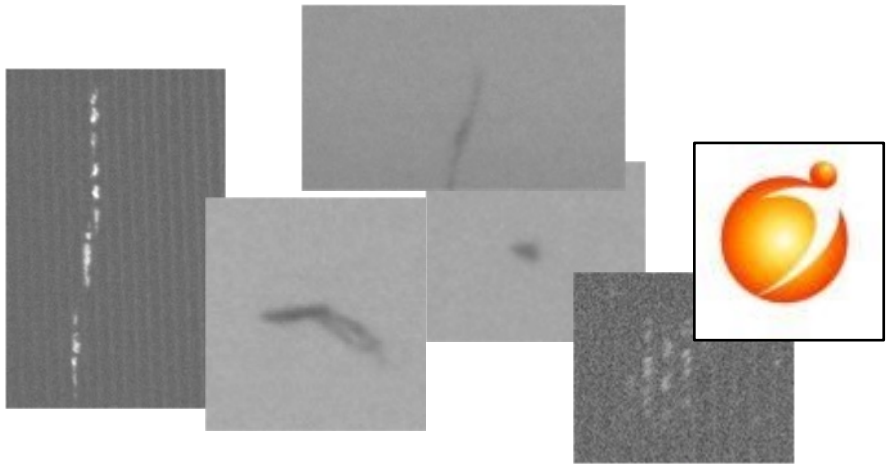
Inventec

3. Laptop Surface AOI



Fail

Pass



Training data

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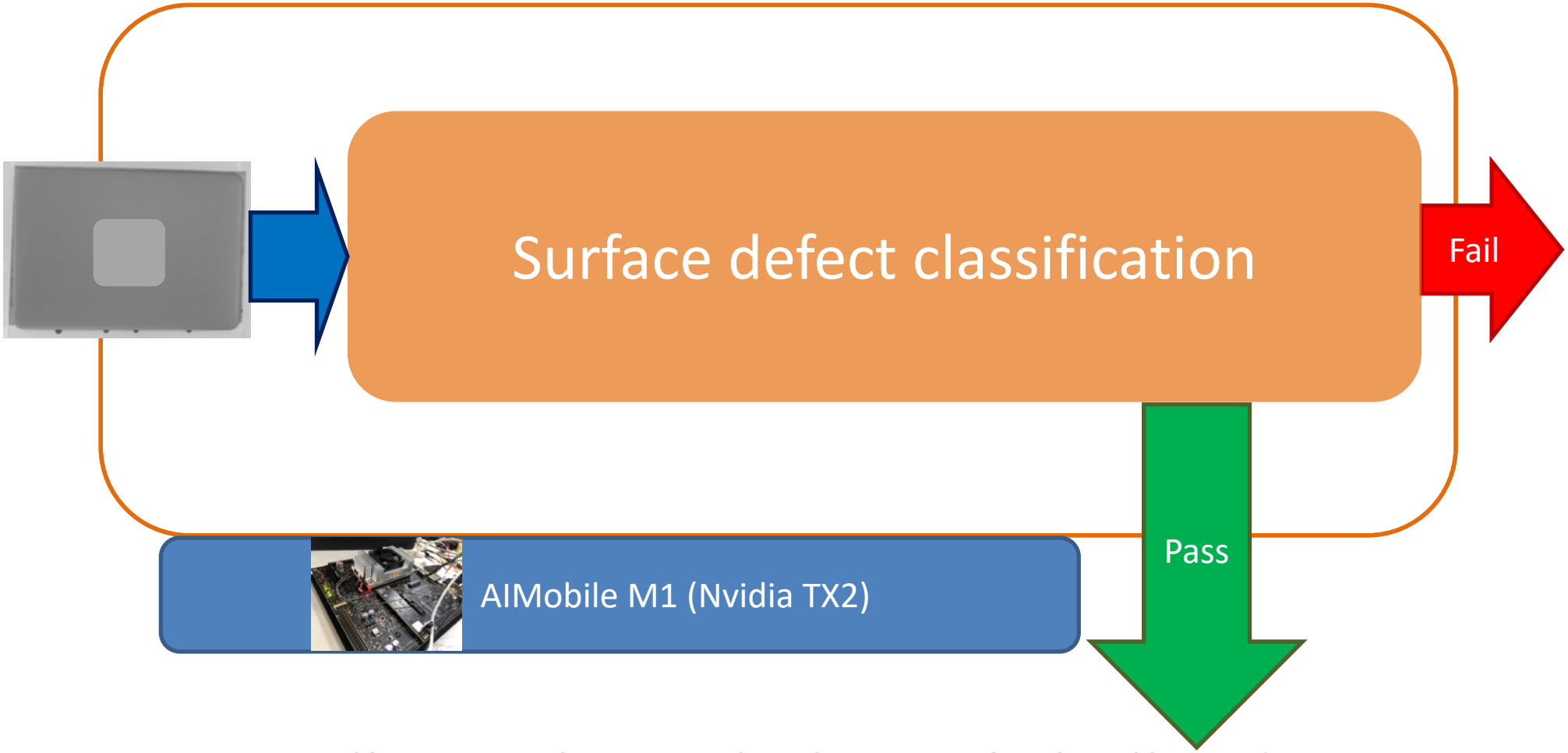
3. Laptop Surface AOI



By: Benson Lin of Skywatch, Trista Chen and Irene Chen of Inventec, Wei-Chao Chen of Skywatch & Inventec
In collaboration with Steven Wang, Sing-Wang Chen, Alfa Shih & Tim Zhang et al @ ICC
Machine manufactured by Jerry Tseng @ Leh-Yeh; Edge machine provided by Mark Lu @ AIMobile

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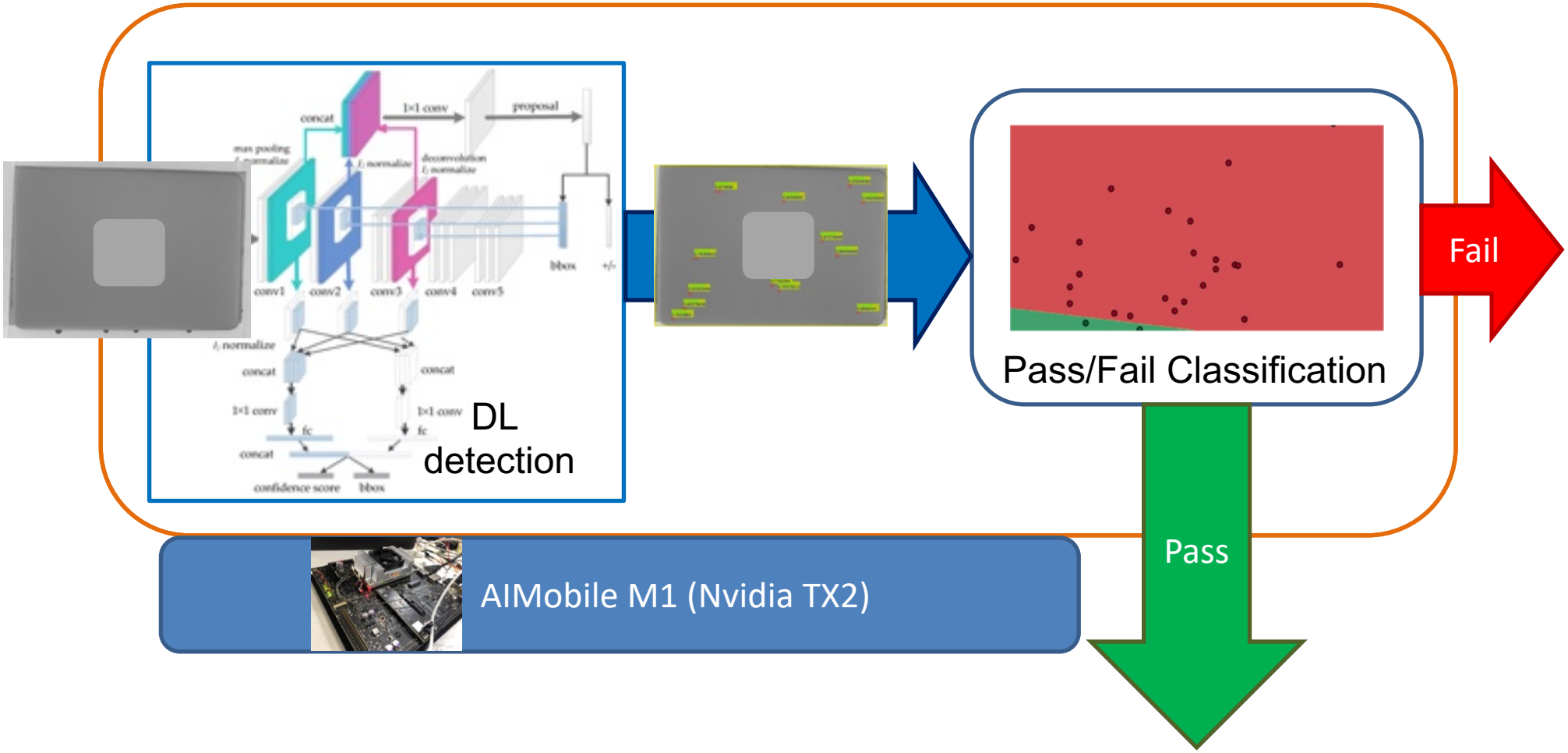
3. Laptop Surface AOI



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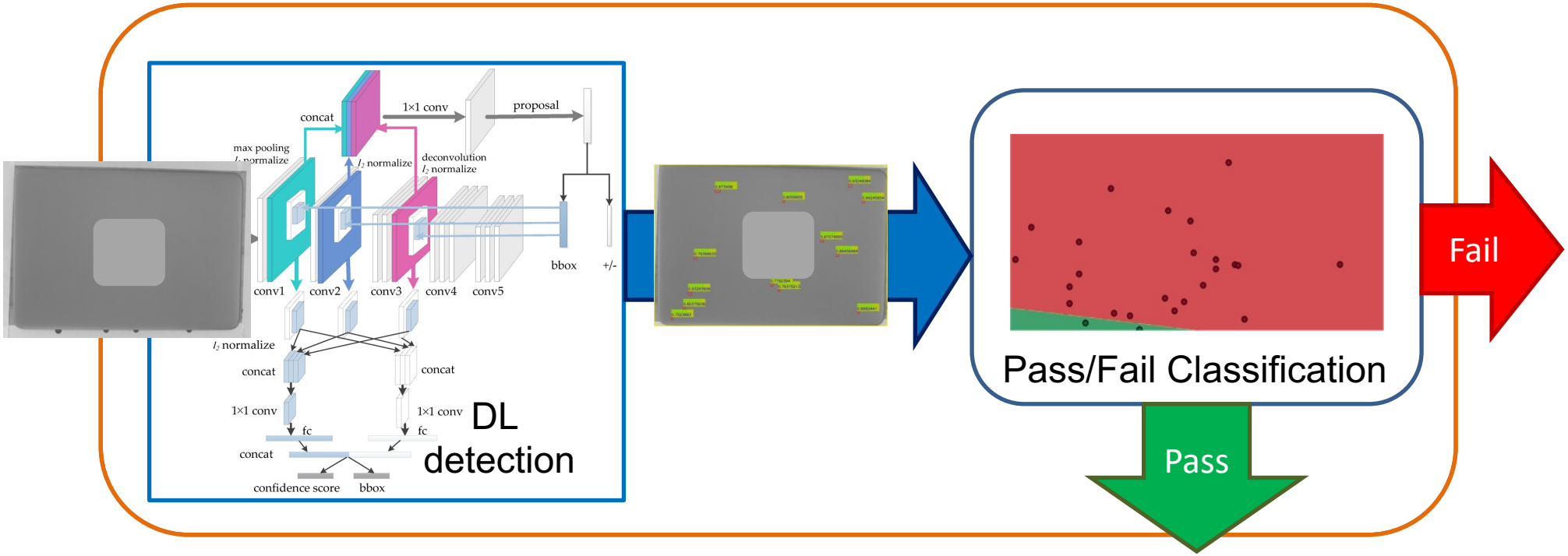
3. Laptop Surface AOI



Stage 1:

Explainable

Stage 2:

Adjustable

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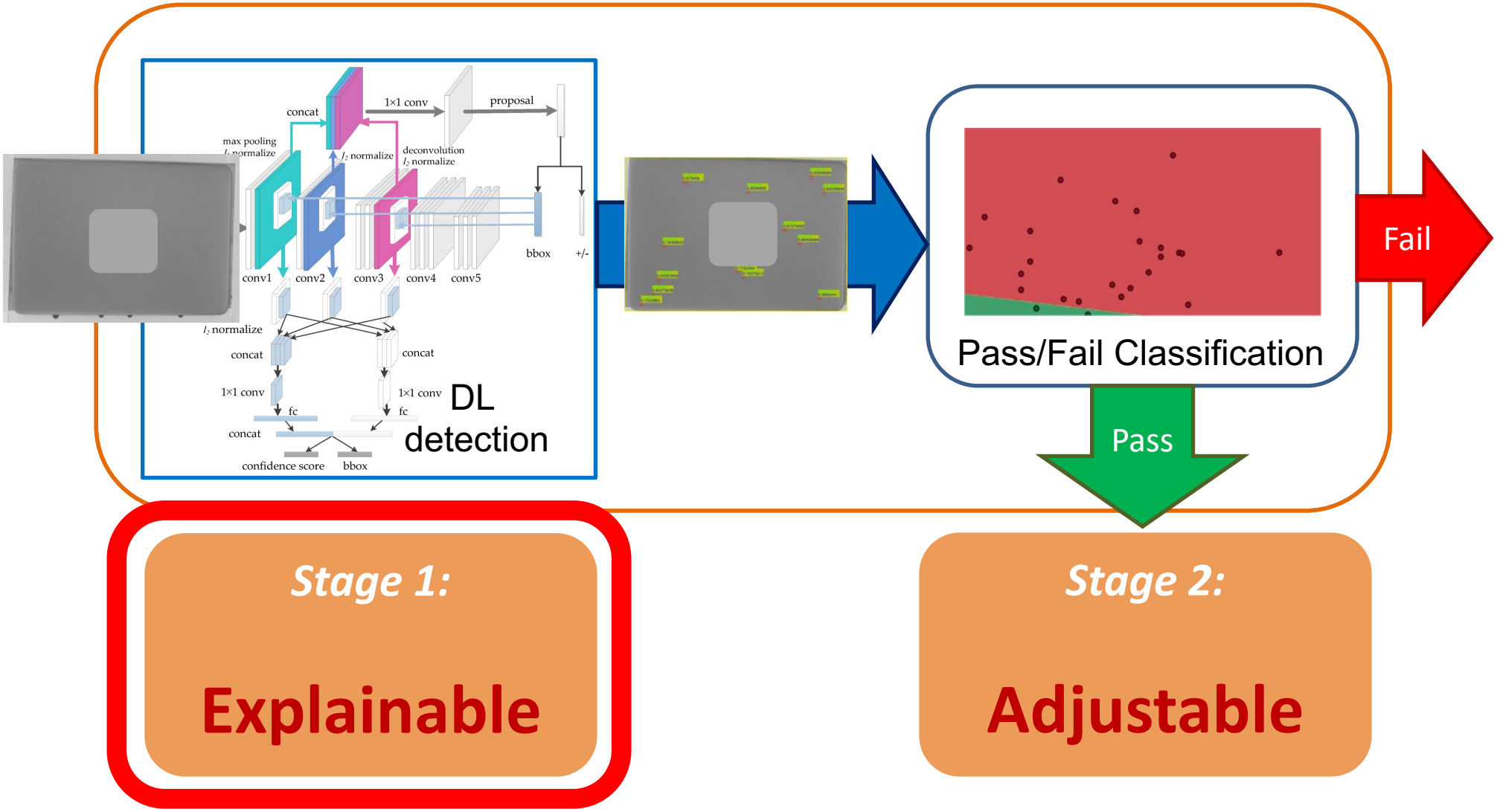
3. Laptop Surface AOI



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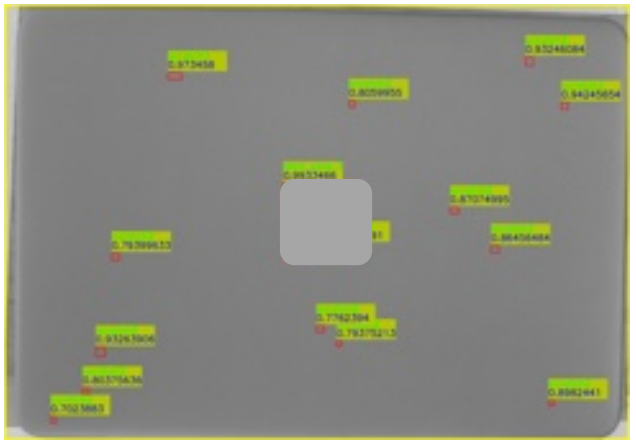
3. Laptop Surface AOI – Explainable

Why did it pass/fail?

- Defect type
- Defect count
- Defect size



Defect type	Class A spec	Class B spec
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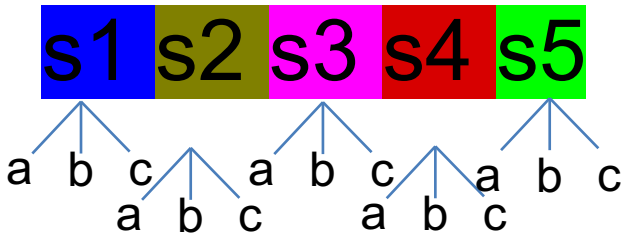
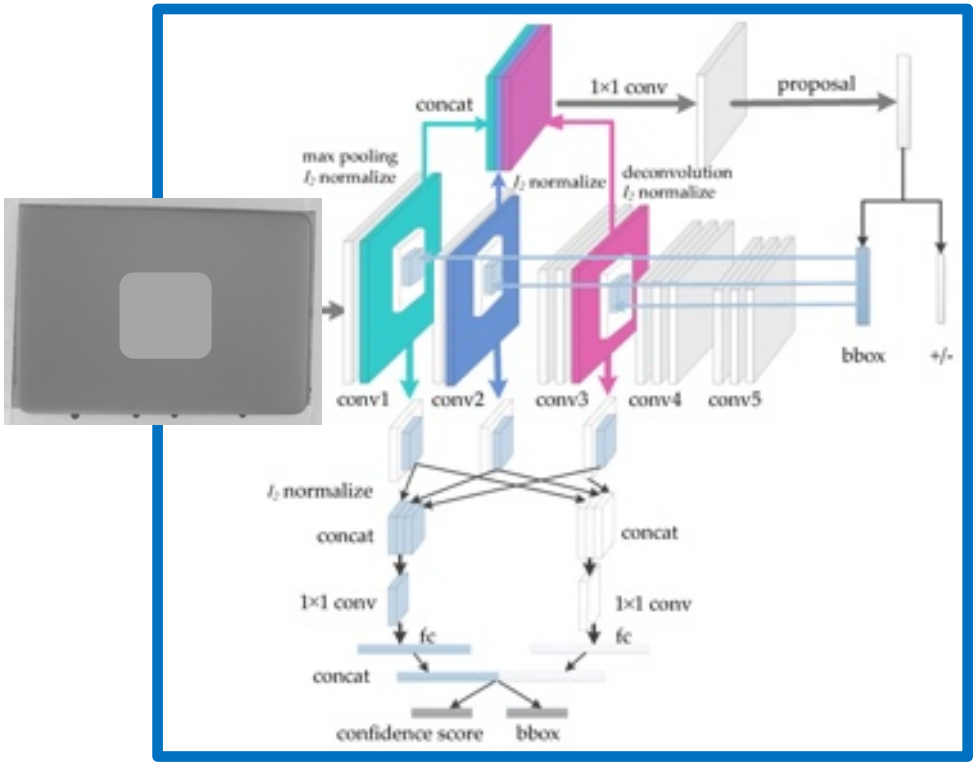
…		

Defect class cluster analysis

Defect types:





15 classes ?

Stage-1 multi-class detector

5 classes ?

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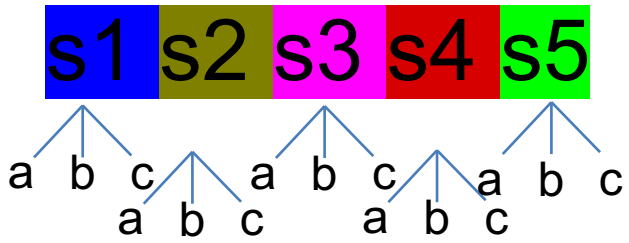
Defect class cluster analysis

Defect types:



~~15 classes~~

5 classes

Input

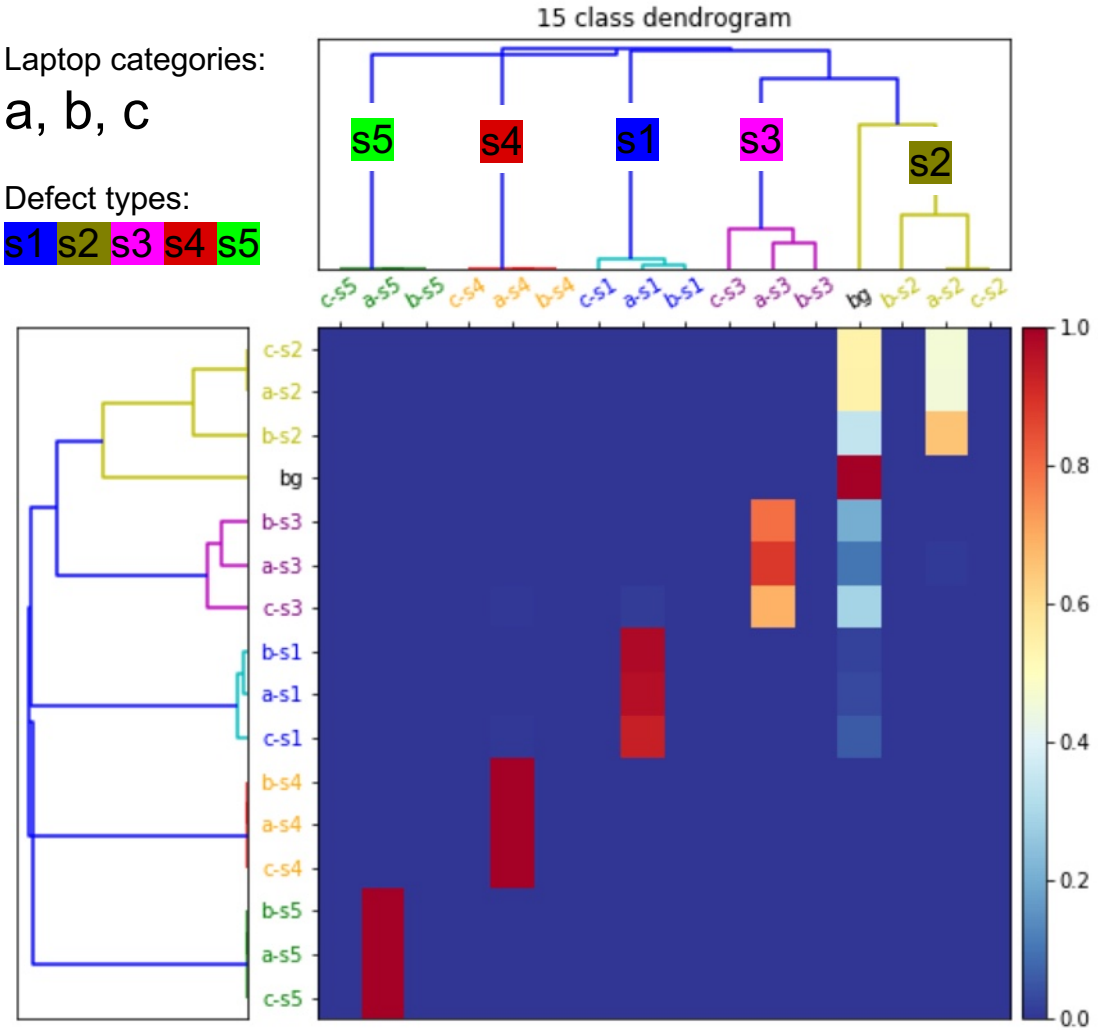
Output

Laptop categories:

a, b, c

Defect types:

s1 s2 s3 s4 s5



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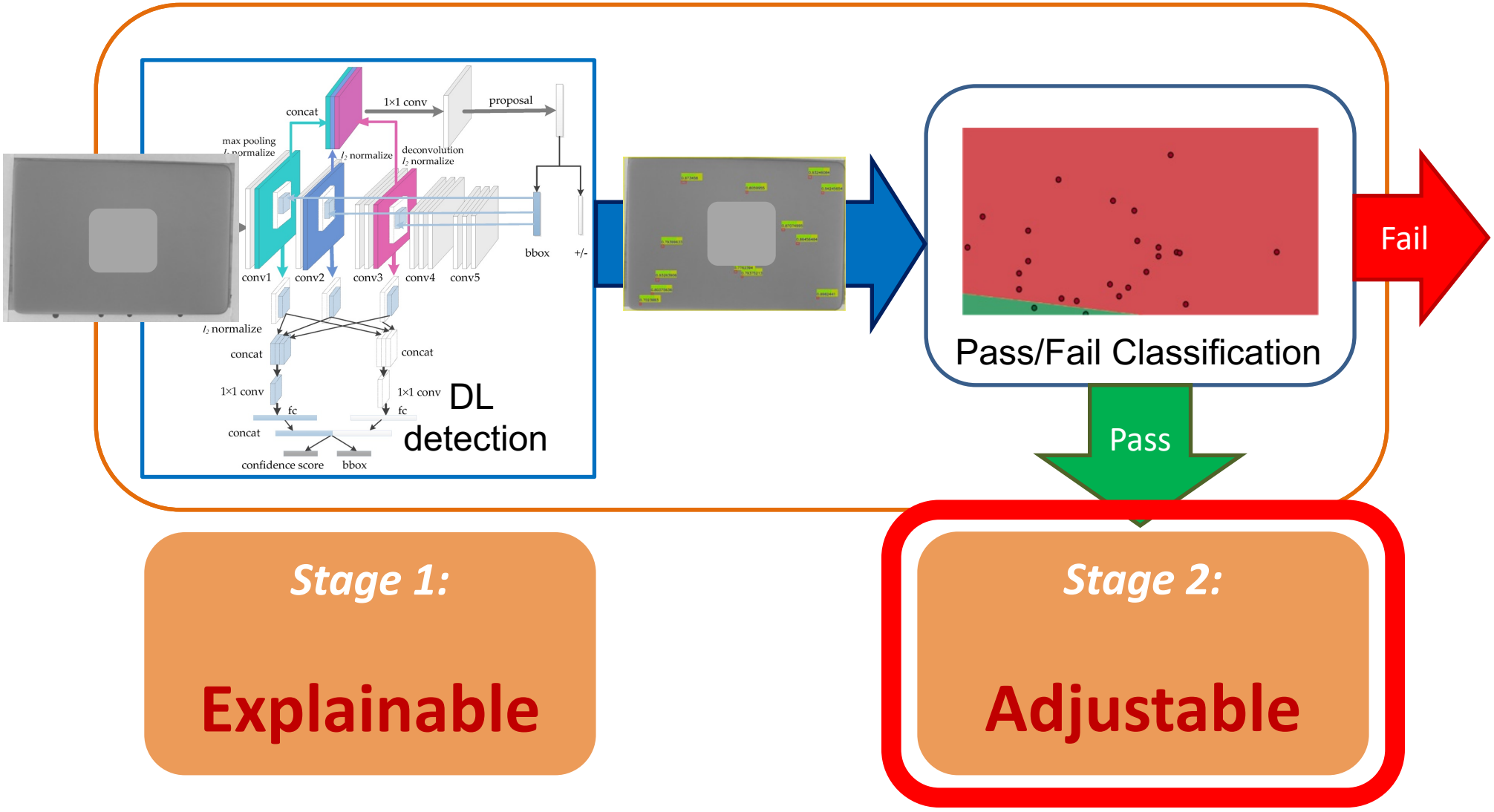
3. Laptop Surface AOI



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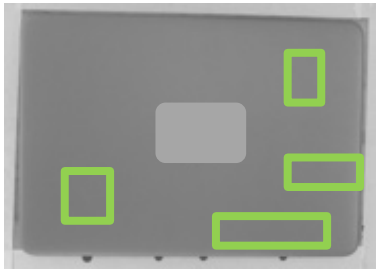
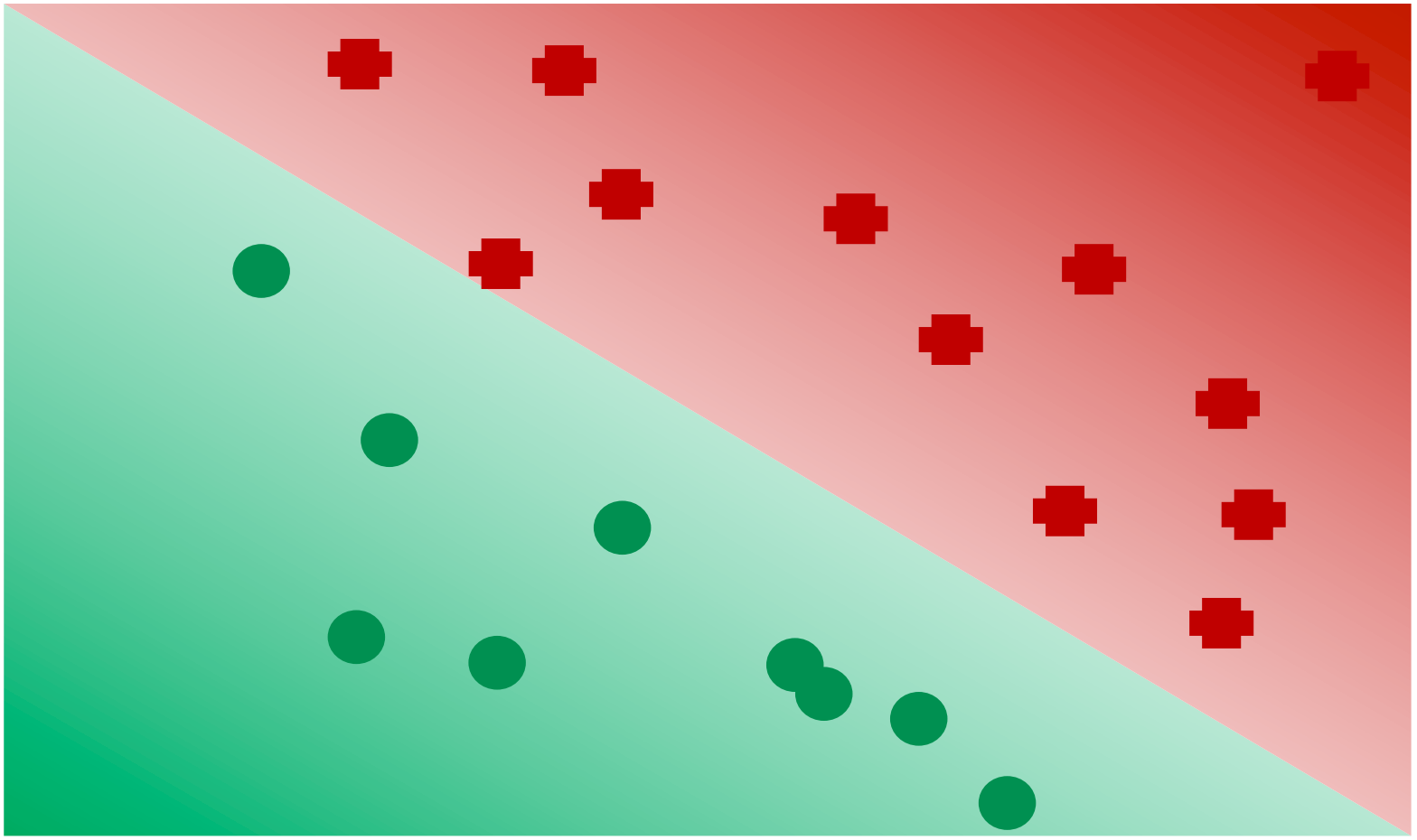
3. Laptop Surface AOI – Adjustable





Class A
2 lines 2 dots

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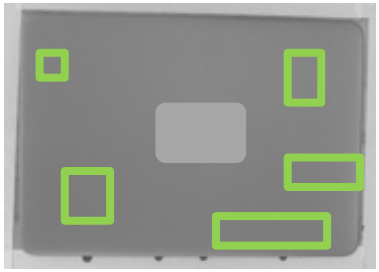
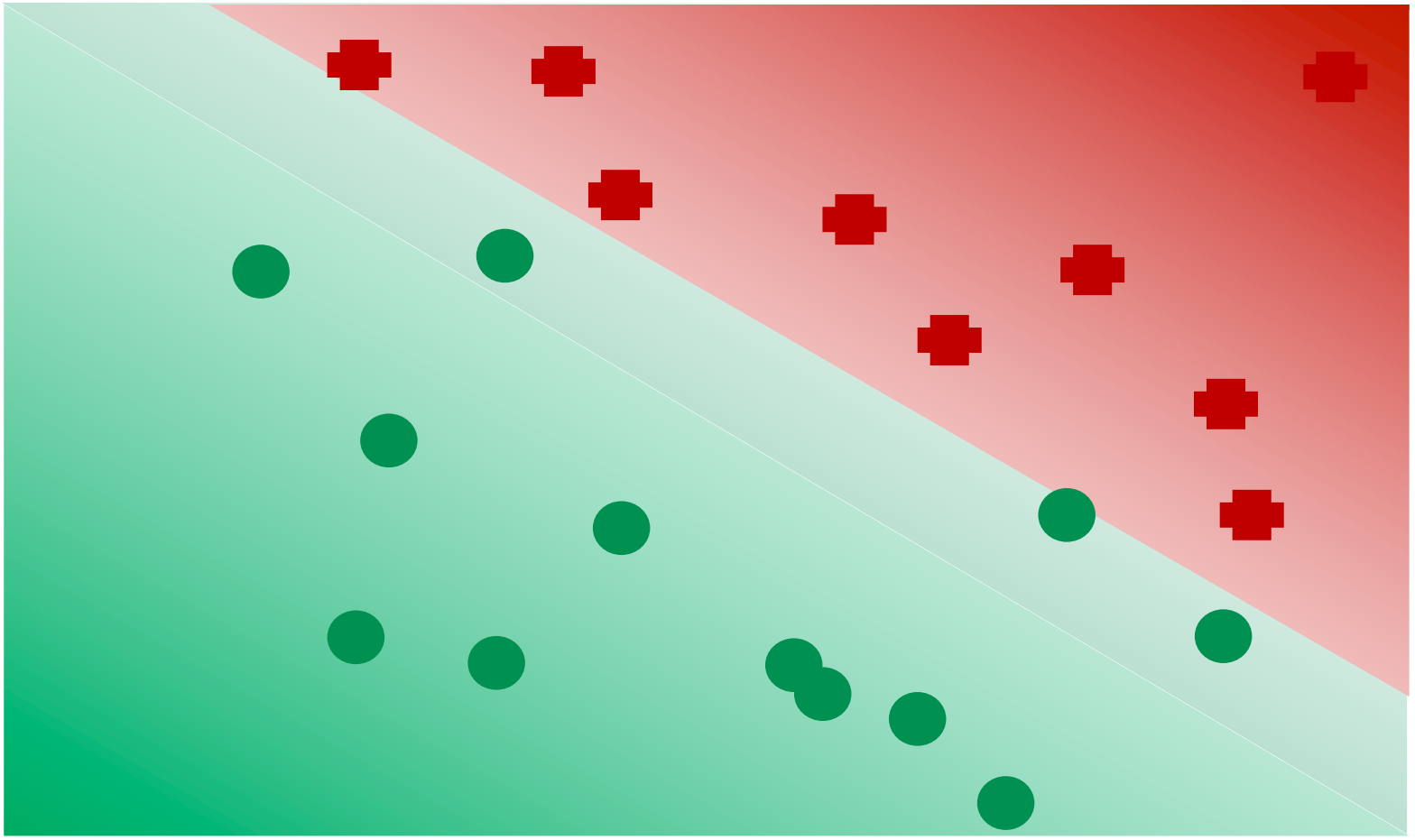
3. Laptop Surface AOI – Adjustable

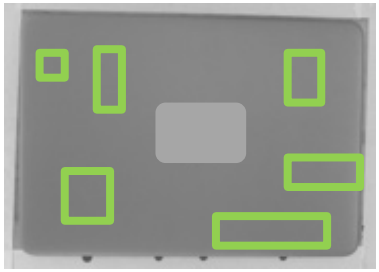


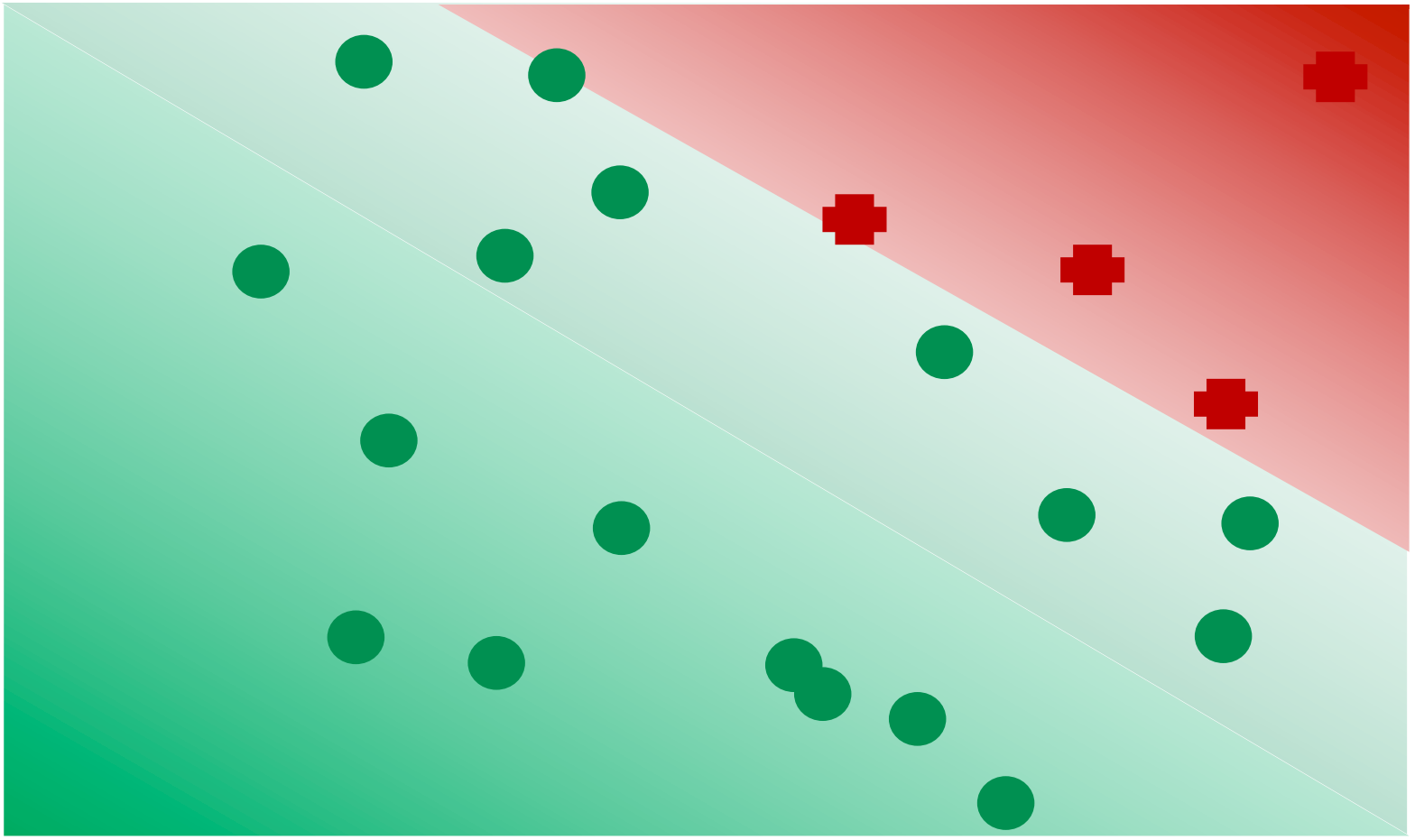


Class B

Inventec

3. Laptop Surface AOI – Adjustable

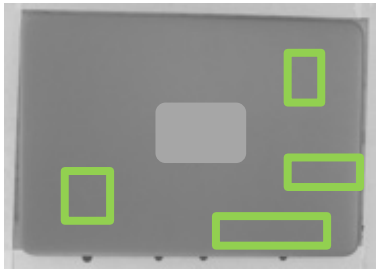


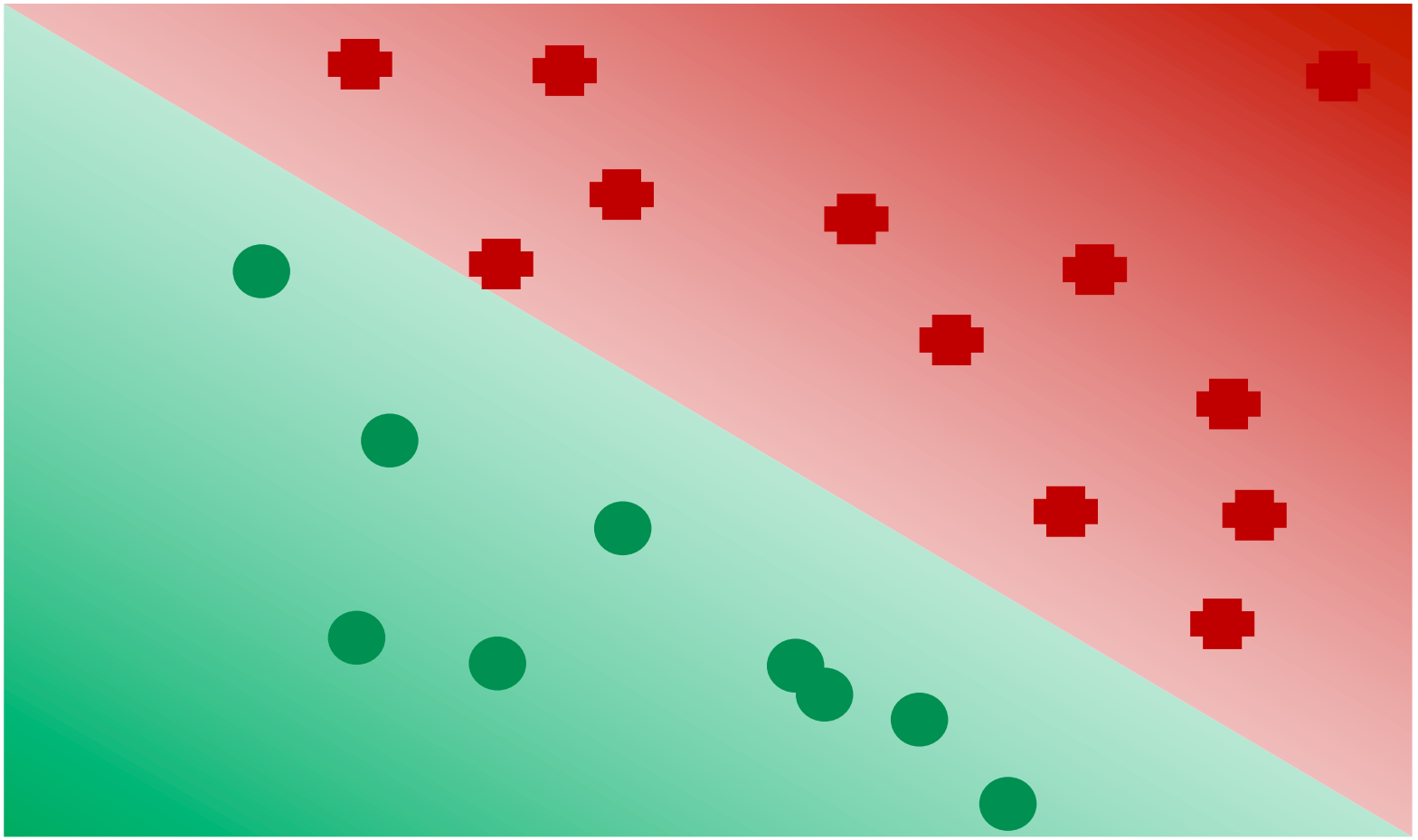


Class C

Inventec

3. Laptop Surface AOI – Adjustable





Class A

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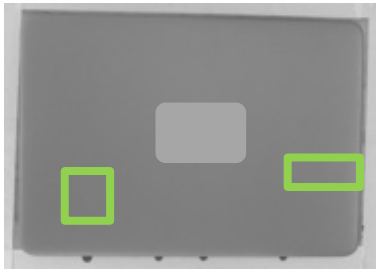
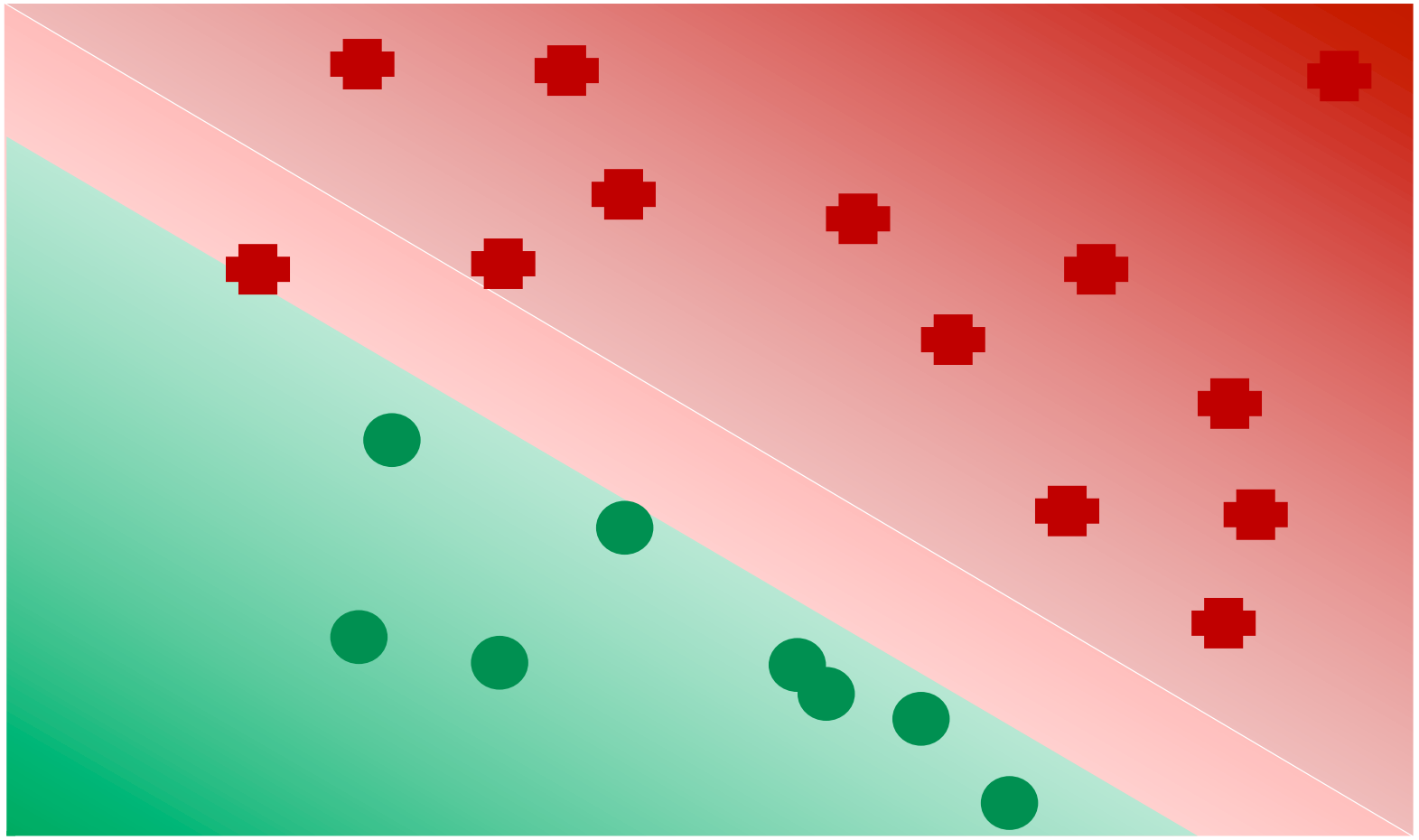
3. Laptop Surface AOI – Adjustable





Class A+

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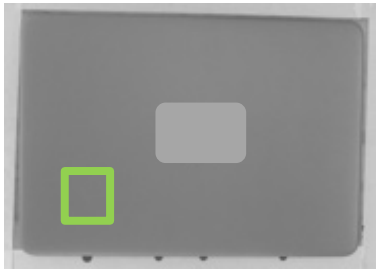
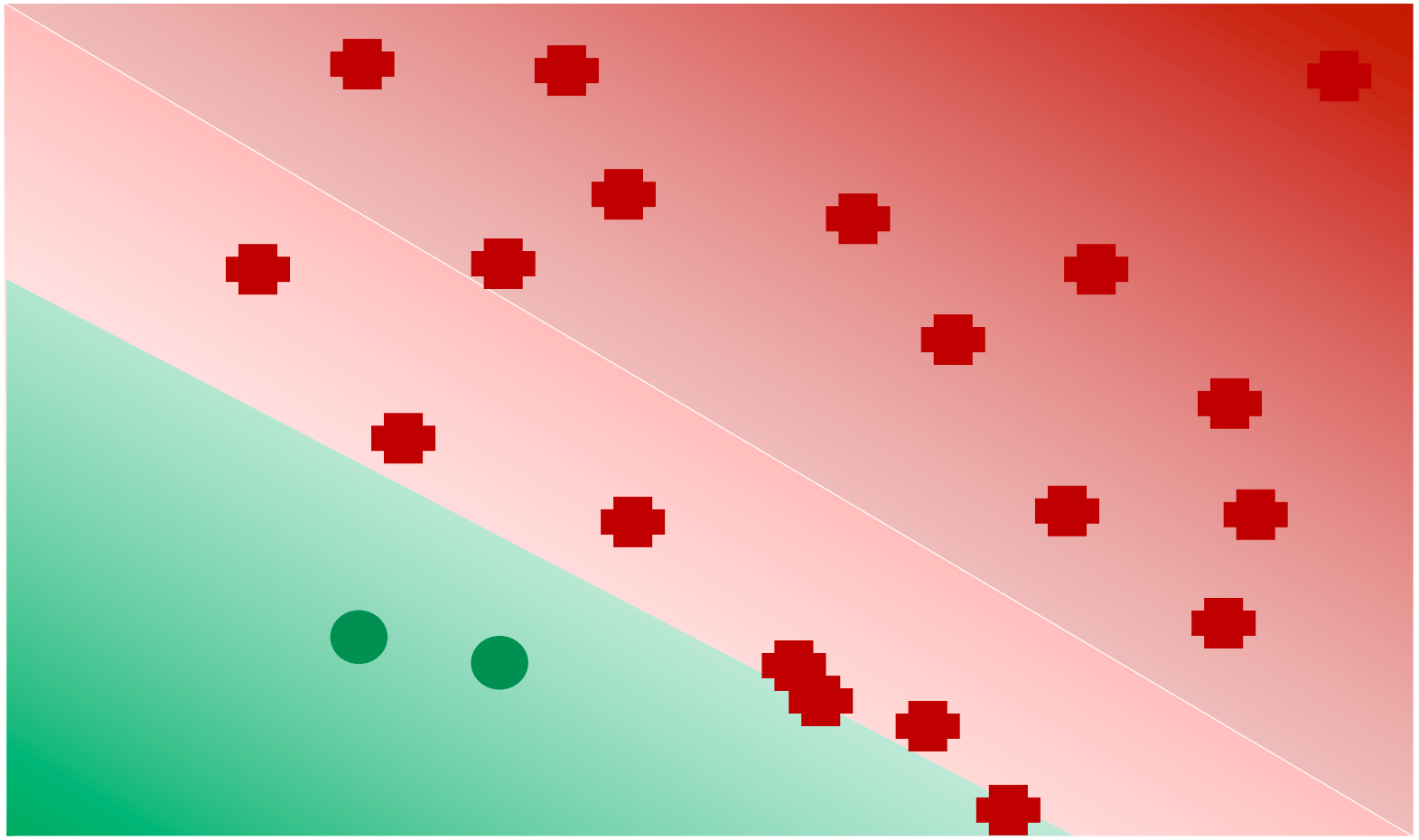
3. Laptop Surface AOI – Adjustable





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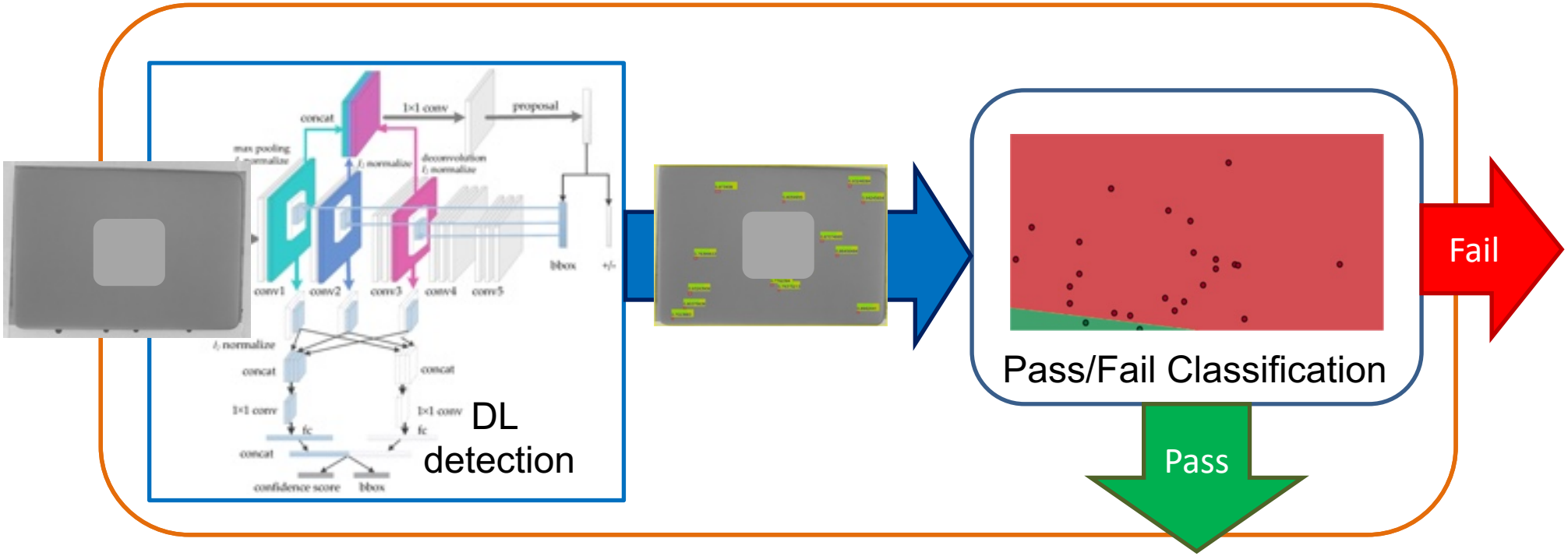
3. Laptop Surface AOI



Stage 1:

Explainable

Stage 2:

Adjustable

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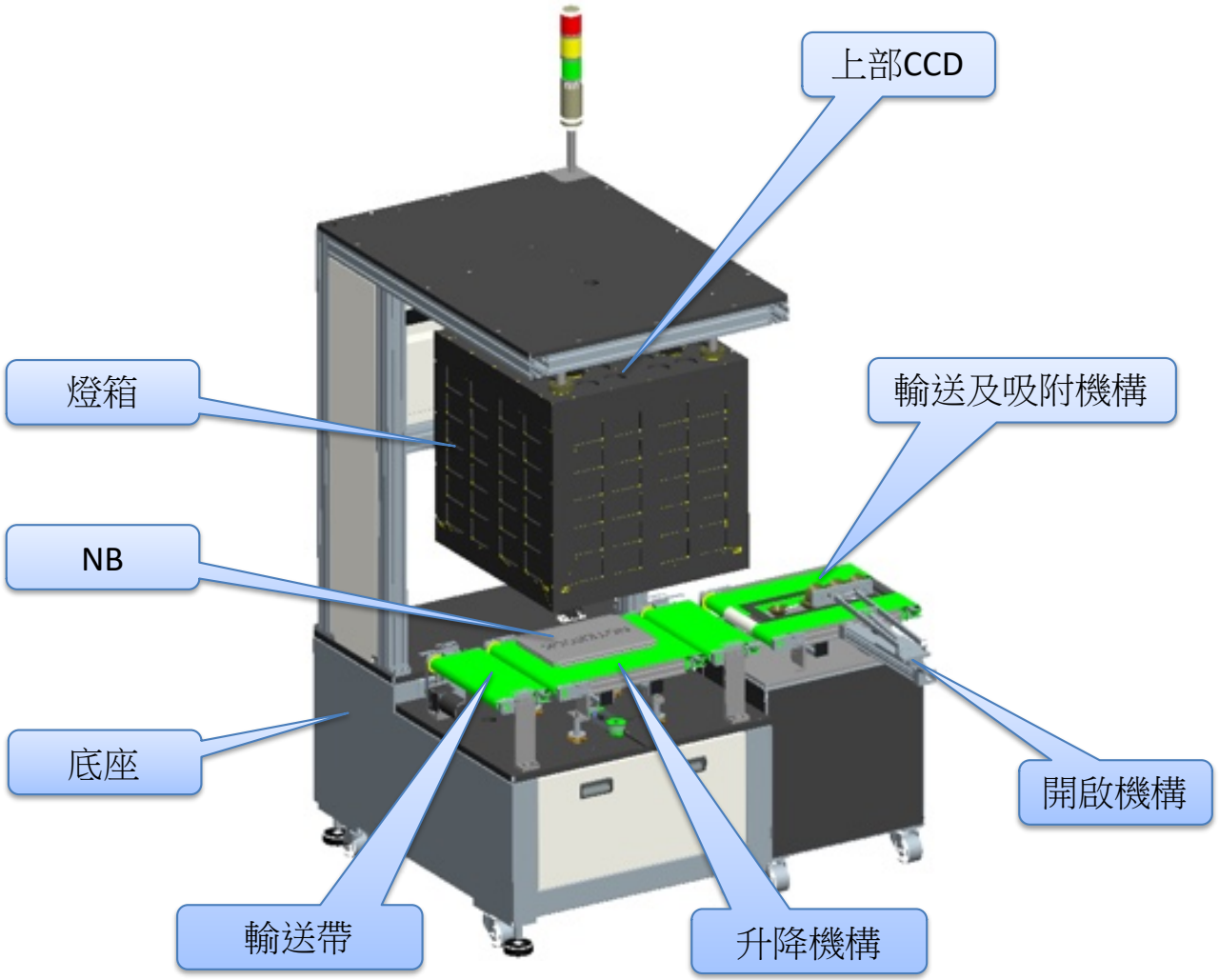
3. Laptop Surface AOI – Factory Prototype



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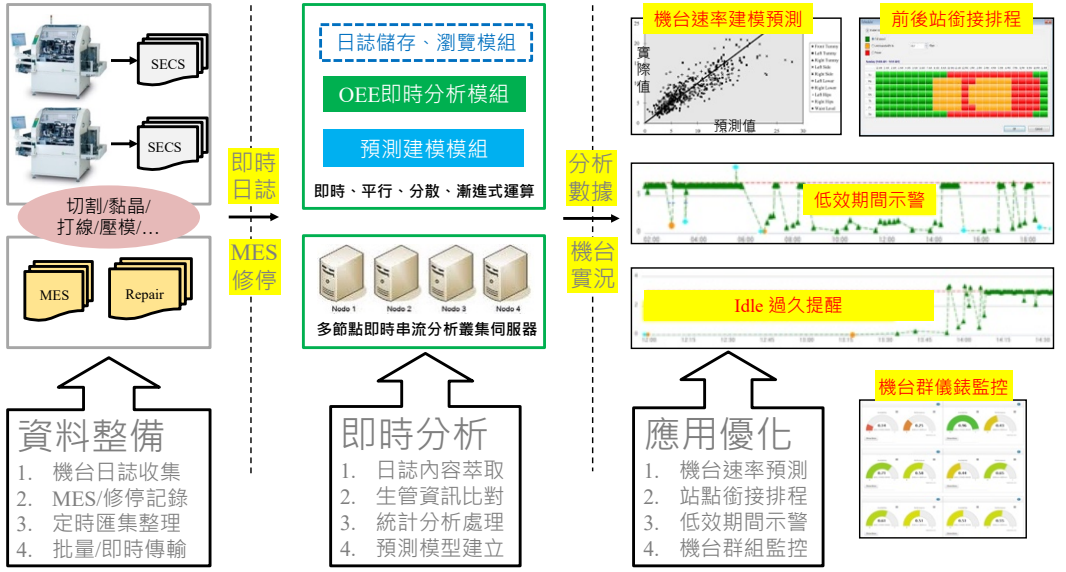
Benefits of AI for Manufacturing

- The Obvious
  - Accuracy
  - Labor Saving ROI

- The Big Scope
  - Consistency
  - Trustable digital record
  - Industry 4.0



Source: Taiwan's Institute for Information Industry (III) 2017

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Benefits of AI for Manufacturing – I4.0

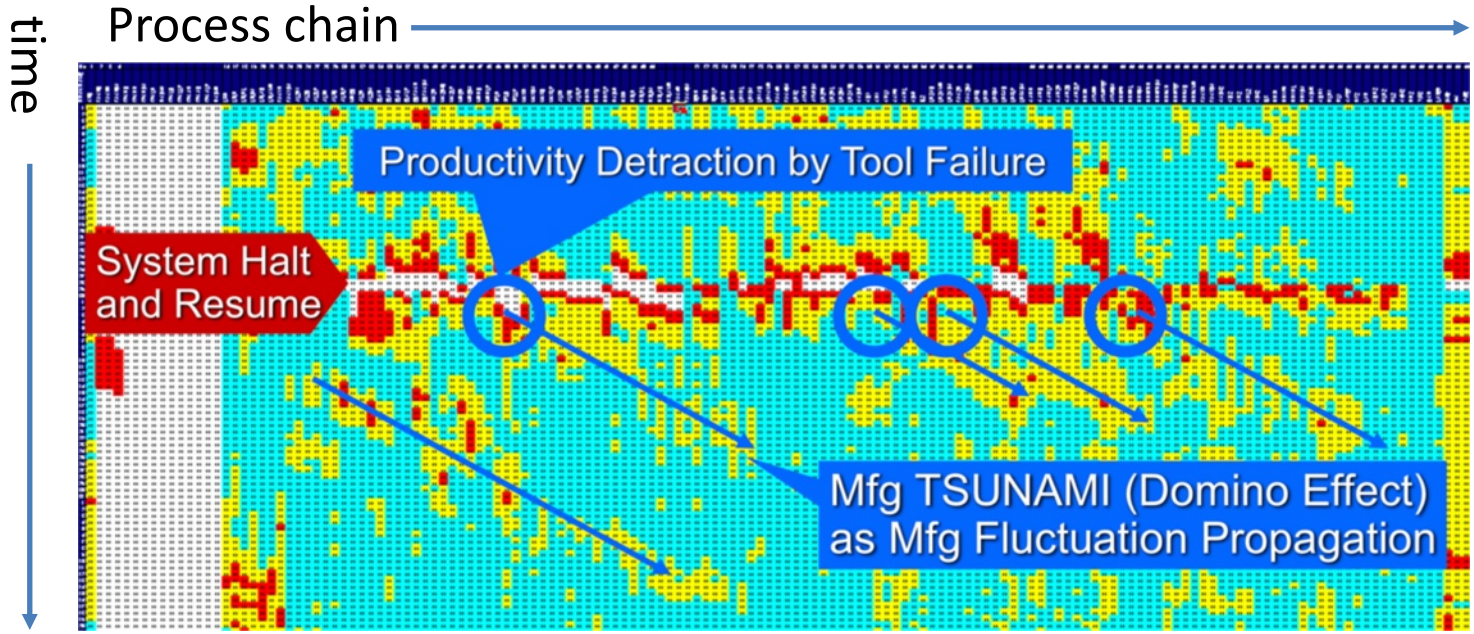

Image source: Hitachi "Factories of the Future", NEXT 2019

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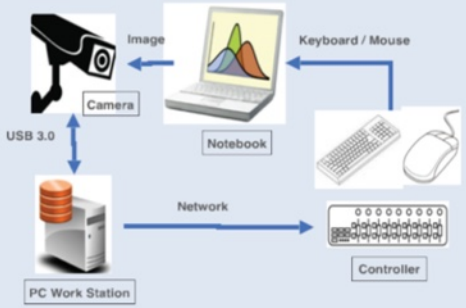
FLOW
AI Data Strategy Partner

Unexpected Bonus:

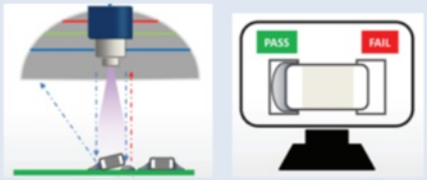
to do well while building your AI engine

*We're on a mission to connect **60,000 residential disabled** in Taiwan to join AI work by providing high-quality data fuels to your AI engines.*



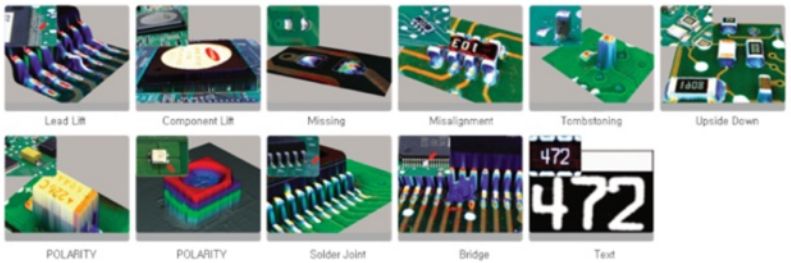
Laptop Testing Robot

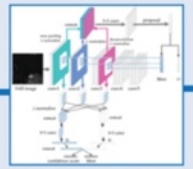
AOI **Re-inspection** for SMT lines and PCBs

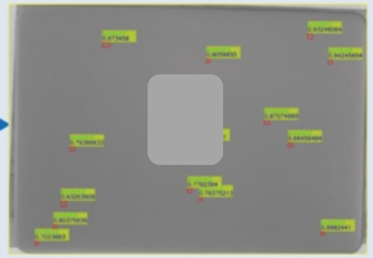


AOI Machine

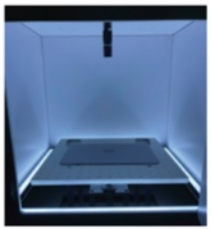
AOI Re-inspection

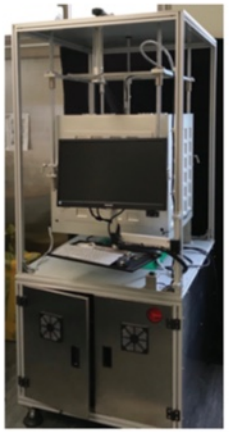






Laptop Surface AOI





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Smart Manufacturing

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GPU TECHNOLOGY CONFERENCE

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Edge AI in Smart Manufacturing: Defect Detection and Beyond

Trista Chen, Chief Scientist of Machine Learning of Inventec

Wei-Chao Chen, Co-founder of Skywatch & Head of Inventec AI Center

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創新 Innovation　品質 Quality　虛心 Open Mind　力行 Execution

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